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Characterization of the Biological Resources of the Water Corridor Units, Big Thicket National Preserve

Prepared by:

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Department of Ecology and
Evolutionary Biology
Rice University

Under Cooperative Agreement with
the National Park Service
Big Thicket National Preserve

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INTRODUCTION

Purpose

The purpose of this document is to assemble information in order to characterize and assess the current knowledge of the natural resources of the water corridors of Big Thicket National Preserve (BTNP). The resources covered in this report include mammals, birds, reptiles, amphibians, fish, and invertebrates, including any species listed as endangered or threatened at the state or federal level. Management considerations related to each faunal group are addressed and more in-depth consideration of several case study species is provided. Last, the possible roles of the water corridors of BTNP in protecting regional biological diversity are considered.

Methods

Information in this report comes from several different sources. Reports of past studies done by and for the National Park Service (NPS) provided the baseline for characterization of resources. Current literature on bottomland hardwood forests (BLHF), riparian systems, conservation biology, and corridor systems was also reviewed. Literature that was cited or consulted during the creation of this document was compiled into a database that includes brief notes about each entry's contents and references to species of interest. The Texas Parks and Wildlife Department (TPWD) was contacted for hunting and trapping information for the region. The U.S. Fish and Wildlife Service (USFWS) provided reports on habitat suitability index models for many of the species found in BTNP. These reports include information about the biology and management of individual species. The USFWS also provided the <u>Report to Congress: Endangered and Threatened Species Recovery Program</u>, which includes recent information about threatened and endangered species.

Species lists were compiled using data from several sources. The initial lists of species using bottomland hardwood forests were created from inventories originally made for the BTNP. Additional data were taken from bottomland hardwood characterizations, e.g., Wharton *et al.* (1980 and 1982), Mitsch and Gosselink (1986) and other published sources. Species listed in the literature were checked against field guides and BTNP reports before being added to the final lists. Actual presence of a species in BTNP itself was determined from survey data within the preserve (Deuel and Fisher

1977, Fisher 1974, Ramsey 1980, Williams 1981, Schmidly *et al.* 1979, Fisher and Rainwater 1978, Connor 1977, Suttkus and Clemmer 1979, McCollough 1974, Bass 1979, and Howard 1973). The species lists for each faunal group were compiled into a database that includes bottomland hardwood forest status, BTNP presence, threatened or endangered listing, and, in some cases, literature references to that species (Harcombe, personal communication).[1]

Corridor Streams

Rivers of the coastal plain of the Southeastern United States are characterized by strong annual cycles, with high flows occurring in winter and spring when evapotranspiration is low and low flows occurring during summer and fall when vegetation cover in the watersheds evapotranspires much of the precipitation that falls. The larger rivers that originate in the continental interior frequently carry high amounts of suspended sediments, and are therefore turbid, chocolate brown in color, and high in conductivity. These rivers are often referred to as "alluvial" or "brown-water" rivers. In the Big Thicket, the Neches River is typical of brown-water rivers.

The smaller streams that originate primarily within the outer coastal plain also fluctuate in flow volume, but their flow is more subject to local rainfall events. Those that drain areas of predominantly sandy, acid soils are sometimes termed "blackwater" streams, owing to a high concentrations of organic acids in the water and low turbidity. Of the streams in the study area, Village Creek is most nearly typical of blackwater streams. Village Creek was not a part of BTNP when this study was initiated, but much of the information in this report applies to that stream as well. Menard Creek and Little Pine Island Bayou are small and of variable flow like blackwater streams, but are more turbid and of higher conductivity like alluvial streams. The higher turbidity and conductivity may be caused by presence of finer-textured substrates such as silts and clays, some with a high calcium content, in their watersheds.

Water Corridors of BTNP

There are three primary water corridors within Big Thicket National Preserve: Menard Creek, Neches River, and Little Pine Island Bayou (Fig. 1). Together they comprise approximately four percent of the total area of Big Thicket. Each of the waterways has some characteristics typical of blackwater streams (Table 1).

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[1] This database file is located on Global Changer\Lab Projects\WCMP\Filemaker files\WCMP species list.

Table 1: Water Quality Parameters for selected southern rivers and streams (abstracted from USGS data and work of Benke *et al.* 1979, 1984, 1985 and Meyer 1992 including the three water corridor unit streams in BTNP)[2].

River	Discharge [m^3/s]	Temp [°C]	pH	Conduct. [µmhos/cm]	D.O. [mg/L]	Turbidity [NTU*]
Ogeechee River	115.0	18.7	6.9	47 - 104	7.3	
Satilla River	117.0	19.0	4.9	40 - 59		6.7
Sabine River	213.9	20.7		347.0		
Trinity River	193.9	20.4		168.0		
Neches River	134.0	21.0	5.9	157.9	5.9	2.0 - 74.6
Menard Creek	4.8	19.7	6.6	159.9	7.9	3.9 - 45.3
Little Pine Island Bayou	8.2	20.5	6.4	325.1	6.1	5.3 - 114.2
Village Creek	20.0	19.0	6.2	104.0		

*Nephelometric Turbidity Units

Menard Creek

The Menard Creek Corridor Unit (3350 acres) runs through Polk, Hardin and Liberty Counties (Fig. 1). The creek itself originates in central Polk county and flows 77 km before it enters the Trinity River. The average discharge of Menard Creek is 4.8 cubic meters per second (Table 1).

Neches River

The Neches River is large, draining approximately 26,000 km^2 in East Texas. The vegetation surrounding it is largely bottomland hardwood forest. The lower Neches is industrialized and provides water for the Beaumont-Port Arthur area. While the Neches River has some characteristics of a blackwater river, such as high total organic carbon, its other characteristics, such as high turbidity and a high ratio of dissolved inorganics to organics, are not typical of blackwater rivers. Average flow of the Neches is 134 cubic meters per second. The BTNP units that include portions of Neches River are: Upper Neches River Corridor Unit (3775 acres) in Jasper, Tyler and Hardin Counties; Neches Bottom and Jack Gore Baygall Unit (13,000 acres) in Hardin, Jasper and Orange Counties; Lower Neches River Corridor Unit (2600 acres) in Hardin, Jasper and Orange Counties; and Beaumont Unit (6218 acres) in Orange, Hardin and Jefferson Counties (Fig. 1).

2 Ogeechee River and Satilla River are typical blackwater rivers. Sabine River and Trinity River are the rivers adjacent to BTNP on the east and west. Neches River, Menard Creek, Little Pine Island Bayou, and Village Creek are BTNP waterways.

Little Pine Island Bayou

The Little Pine Island-Pine Island Bayou Corridor Unit (2100 acres) runs through Hardin and Jefferson Counties (Fig. 1). Pine Island Bayou originates in eastern Polk and Liberty counties and flows 93 km into the Neches River. Little Pine Island Bayou is its major tributary and flows 74 km into Pine Island Bayou. Little Pine Island flows at an average rate of 8.2 cubic meters per second.

Village Creek

Originating in Tyler, Polk, and Hardin Counties, Village Creek flows 53 miles into the Neches River. Most of the area bordering the creek is forest or unirrigated agricultural land. Less than two percent of the area is urban. However, 3789 residences in the watershed relied on individual septic systems in 1978 and fecal coliform was still listed as a water quality problem in 1994 (Hall and Bruce 1996).

Vegetation of BTNP

This summary of the vegetation of the Big Thicket is drawn primarily from a monograph (Marks and Harcombe 1981) describing the vegetation of the entire Preserve and is presented here as background for the descriptions of each of the major faunal groups that comprise the rest of this document. There is little upland within the water corridors, but for the sake of completeness, all types will be briefly described. The Little Pine Island Bayou Corridor Unit was not mapped by Marks and Harcombe, so any vegetation types unique to it will not be discussed here.

Vegetation type names include physiographic position and community physiognomy, combined with the type or common names of dominant or important trees. Physiographic position indicates something about the relative elevation of a type and its position in the landscape. The four physiographic types are upland, slope, floodplain, and flatland. Community physiognomy refers to the vegetation structure as indicated by height and growth form of the dominant vegetation. The three types identified are forest, savanna, and shrub thicket. The local name "baygall" was used as a descriptor for wet shrub thickets, "sandhill" was used as a descriptor for a very dry sandy hill or ridge, and "wetland" and "swamp" were used as additional descriptors for wetland forests.

The vegetation is divided into four broad types: uplands, slopes, floodplains, and flats. These types are further subdivided as follows:

<u>Uplands</u>
Sandhill Pine Forest
Upland Pine Forest
Wetland Pine Savanna

<u>Slopes</u>
Upper Slope Pine Oak Forest
Mid Slope Oak Pine Forest
Lower Slope Hardwood Pine Forest

<u>Floodplains</u>
Floodplain Hardwood Pine Forest
Floodplain Hardwood Forest
Wetland Baygall Shrub Thicket
Swamp Cypress Tupelo Forest

<u>Flatlands</u>
Flatland Hardwood Forest

Uplands

Sandhill Pine Forest is found on level, deep, sandy terraces associated with river bluffs. Upland Pine Forest is found on level to gently rolling hilltops with sandy surface soils. Wetland Pine Savanna occurs within the uplands on shallow, poorly-drained depressions with slow drainage due to a subsurface clay layer (clay pans). *Pinus palustris* (longleaf pine) is a dominant in the upland types. In the Sandhill Pine Forest, *P. palustris* is widely scattered, with a subcanopy layer of *Quercus incana* (bluejack oak). In the Wetland Pine Savanna, it is also widely scattered, with a ground layer of wetland herbs and shrubs.

Slopes

In the slope forests, *P. echinata* (shortleaf pine) and *P. taeda* (loblolly pine) replace *P. palustris* as the dominant pines. *Q. falcata* (southern red oak), *Q. alba* (white oak), *Magnolia grandiflora* (southern magnolia), and *Fagus grandifolia* (American beech) are the principal overstory hardwoods. In Upper Slope Pine Oak, *P. echinata*, *P. taeda* and *Q. falcata* contribute more than 50 percent of the basal area. In Mid Slope Oak

Pine, *P. taeda*, *Q. alba*, and *P. echinata* dominate. In Lower Slope Hardwood Pine, *P. taeda*, *F. grandifolia*, *M. grandiflora*, and *Q. alba* dominate.

Floodplains

The corridor units are composed primarily of floodplain forests. Floodplains include the broad, flat terraces between the bluffs of the Neches River and along some of the major streams. Floodplain Hardwood Forest occurs on low terraces along the Neches River and in strips along Pine Island Bayou, Village Creek and its tributaries, and Menard Creek. This forest type is dominated in the overstory by *Liquidambar styraciflua* (sweetgum) and *Q. nigra* (water oak), often with a dense subcanopy layer formed by the small tree *Carpinus caroliniana* (ironwood). Smaller stream floodplains support Floodplain Hardwood Pine Forest, with *F. grandifolia* and *P. taeda* as important dominants, but also containing *C. caroliniana* as an important subcanopy tree. Swamp Cypress Tupelo Forest occurs in deep sloughs and oxbow lakes of major floodplains and is dominated by *Taxodium distichum* (bald cypress) and *Nyssa aquatica* (water tupelo). Wetland Baygall Shrub Thicket occurs at all physiographic positions, including floodplains, slopes and uplands. This type forms in response to the presence of near-surface seepage water (subsurface drainage). Dominant species include *Nyssa sylvatica* (black tupelo), *Quercus laurifolia* (laurel oak), *Acer rubrum* (red maple), and *Magnolia virginiana* (sweet bay). Floodplain Hardwood is the predominant corridor type. Since these forests are most frequently referred to in the literature as Bottomland Hardwood forests (BLHF), that designation will be adopted here.

Flatlands

Flatlands are level, low-elevation interdistributary flats or terraces associated with the ancient Trinity River. Surface drainage patterns are poorly developed because of the topography and fine soil texture, so that standing water is common after heavy rains. *Q. michauxii* (basket oak), *Q. phellos* (willow oak), *Q. laurifolia* , *P. taeda*, and *Fraxinus pensylvanica* (green ash) are dominant trees in Flatland Hardwood Forest. It is also characterized by the presence of *Sabal minor* (dwarf palmetto).

Fig. 1: Neches/Angelina River Basin and the Big Thicket National Preserve

BIRDS

Birds are the most visible animals of BTNP and, by number of species, the most diverse of the faunal groups. McMahan and Frye (1986) identified 273 bird species that are inhabitants of BLHF of the southeastern United States. Of those species, 101 are known or believed to breed in bottomlands. Burdick *et al.* (1989) listed 61 species believed to be obligate or facultative inhabitants of BTHF. While the avifauna of BTNP has been surveyed several times, Fisher (1974) recorded the most species: 196, or more than seventy percent of the species McMahan and Frye identified as BLHF inhabitants.

The most thorough survey of BTNP avifauna was completed by Deuel and Fisher (1977). They investigated the relative abundance of the bird species in four different forest types: loblolly pine-hardwood, floodplain cypress-hardwood, shortleaf pine-hardwood, and palmetto-hardwood. They conducted 29 mile-long transect censuses, identifying birds between 0 and 412 feet on either side of the transect line by auditory or visual detection. They also conducted four canoe censuses, two along Pine Island Bayou and one each on the Neches River and Village Creek. They recorded all birds heard or seen flying over each stream for a total of 128 species and 2167 individuals in their survey, although they suspected that there were more species present than they observed.

There have been no recent comprehensive studies of the avifauna of BTNP. Ramsey (1980) recorded 58 species in weekly walking surveys of the Beaumont Unit in the fall, winter, and spring of 1975-76. Williams (1981), in a bird survey of the Dujay Sanctuary, which is adjacent to the west side of the Lance Rosier Unit, conducted 66 censuses between September 1979 and October 1980 by walking along a 2 km trail loop through the sanctuary. She recorded 78 species and included brief notes on observed behaviors or habitat preference for each species in her survey.

The most abundant streamside species in the Big Thicket are white-eyed vireo (*Vireo griseus*), red-eyed vireo (*Vireo olivaceus*), northern cardinal (*Cardinalis cardinalis*), and northern parula (*Parula americana*). The northern parula appears to be mostly confined to floodplain cypress-hardwood forest, but the other three species are found in all habitat types. Some birds, such as the American redstart (*Setophaga ruticilla*), the wood duck (*Aix sponsa*), and the northern parula use the bottomland hardwood forests for their breeding grounds (Deuel and Fisher 1977). Williams (1981) also noted that the American redstart is known to breed in bottomland forests along many major streams in east Texas. The chimney swift (*Chaetura pelagica*) was also commonly observed near water (Williams 1981). Other birds known to be present in BTNP which depend on riparian or forested swamps for habitat are the Louisiana waterthrush (*Seiurus*

motacilla), prothonotary warbler (*Protonotaria citrea*), Swainson's warbler (*Limnothlypis swainsonii*), yellowthroat warbler (*Dendroica dominica*), wood duck, red-shouldered hawk (*Buteo lineatus*), and yellow-crowned night-heron (*Nycticorax violacea*) (Peterson 1967, Deuel and Fisher 1977, Wharton *et al.* 1982, Williams 1981, and Harris and Gallagher 1989).

The birds that are of most interest to river corridor management fall into three groups: neotropical migrants, raptors, and water birds, including both migratory waterfowl and colonial water birds. The nesting needs of these species vary across a wide range of habitat types. Water birds require areas of shrub swamp or forest for nesting sites. Raptors can nest in a variety of habitats, from large trees in BLHF (barred owls and red-shouldered hawks) to lakes and forests of east Texas (bald eagles). Neotropical migrants have diverse requirements for nesting habitat, ranging from open fields and roadsides to dense undergrowth to Spanish Moss.

Neotropical Migrants

Recently, neotropical migrant have been the focus of much attention and research since their numbers appear to be declining. Whether this decline is due to habitat destruction and fragmentation of their breeding grounds here in the U.S. or to deforestation of their wintering grounds in the tropics is not known (Terborgh 1989). Many neotropical migrants breed in BTNP including: great crested flycatcher (*Myiarchus crinitus*), acadian flycatcher (*Empidonax virescens*), eastern wood-pewee (*Contopus virens*), wood thrush (*Hylocichla mustelina*), prothonotary warbler, Swainson's warbler, black-and-white warbler (*Mniotilta varia*), worm-eating warbler (*Helmitheros vermivorus*), yellow-throated warbler, northern parula, hooded warbler (*Wilsonia citrina*), ovenbird *(Seirus aurocapillus)*, Louisiana waterthrush, and Kentucky warbler (*Oporornis formosus*) (Deuel and Fisher 1977). One neotropical migrant, Bachman's warbler (*Vermivora bachmanii*), was once known to breed in east Texas forested swamps, but is now extinct (Peterson 1967). Bachman's warbler bred in natural light gaps of the swamp forests of the southeastern United States. According to Harris (1988b), "The demise of Bachman's warbler is coincident with the dramatic losses of bottomland forest and concurrent increase in open field activities in the Southeastern Coastal Plains."

Waterfowl and Water Birds

Major BTNP water birds include the wood duck, great blue heron (*Ardea herodias*), little blue heron (*Egretta caerulea*), green-backed heron (*Butorides striatus*), snowy egret (*Egretta thula*), snow goose (*Chen caerulescens*), black-crowned night-heron (*Nycticorax nycticorax*), and yellow-crowned night-heron. Yellow-crowned night-heron and wood duck are rarely seen, but when sighted are seen most often in the floodplain cypress-hardwood forest.

Little information existed about the use of the BTNP as a refuge for waterfowl on migration routes or any other year-round residents. However, approximately 30 percent of the North American mallard population winters in the Mississippi Alluvial Valley, which includes East Texas and BTNP. Heitmeyer and Frederickson (1981) believe that critical pre-breeding nutritional needs for mallard ducks are met in bottomland hardwood forests. The forests provide a large acorn crop that is a reliable source of food from year to year. Wood ducks are known to breed in this area, and so the availability of appropriate nesting cavities is crucial to brood success (Frentress 1986).

Frentress (1986) stated that approximately 150 colonies of colonial water birds are found in East Texas. The principal species are: little blue heron, snowy egret, cattle egret (*Bubulcus ibis*), great egret (*Casmerodius albus*), great blue heron, anhinga (*Anhinga anhinga*), and white ibis (*Eudocimus albus*). Other species include the yellow-crowned night-heron and the green-backed heron. Rookeries have been noted in BTNP in the past, but whether there are any currently active is unknown. In 1976, heronries were present at Steinhagen Lake and Cocklebur Bend, both on the Neches River (Bryan *et al.* 1976). Ramsey (1980) recorded the presence of great blue heron, little blue heron, snowy egret, and yellow-crowned night-heron on his survey of the Beaumont Unit. All of these birds were recorded during the months between February and April. Colonial water birds must have forests or shrub swamps for nesting. Also, altered hydrology could influence their prey base. Monitoring of these species populations may serve as a barometer of health of the bottomland hardwood forest (Frentress 1986).

Water quality is also known to affect water birds. Paveglio *et al.* (1992) found that irrigation drainage water was the source of unusually high concentrations of Selenium and Boron in the livers of the water birds in wetlands in California. Selenium is known to adversely affect the reproduction of water birds (Ohlendorf *et al.* 1986). The USFWS provides data on the toxicity of 196 environmental contaminants and pesticides

to water birds (Hill and Camardese 1986). Intermittent monitoring has shown that these contaminants are not a problem in the water corridors of BTNP (Hughes *et al.* 1987).

Raptors

Little is known about the use of BTNP rivers by raptors. These areas could be used by bald eagles (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), and American swallow-tailed kites (*Elanoides forficatus*), since all are facultative inhabitants of bottomland hardwood forest and were historically known to breed in East Texas (Peterson 1967). Also, the USFWS lists Pine Island Bayou as a breeding area for the Mississippi kite (*Ictinia mississippiensis*) (Halstead 1981).

Bald eagles, listed at the state and federal levels as endangered, prefer to feed in open waters, but will often feed in wide rivers such as the Neches. Although bald eagles presently seem to prefer mature pine stands, they sometimes nests in the river habitats of East Texas (Mitchell 1992 and Dan Boone, TPWD, personal communication). To the west, beyond the range of the pine forests, bald eagles commonly nest in BLHF, indicating that this preference for pine stands could be a recent phenomenon (Mark Mitchell, personal communication). The creation of reservoirs may have caused a shift in nesting out of BLHF habitat to more favorable nesting sites. TPWD has conducted annual surveys of bald eagle nests since 1981 (Mitchell 1992). Though no nest sites have been observed in BTNP, three nests were seen in Polk County in 1991-92. The only active nest was in a mature pine stand adjacent to Lake Livingston. Management guidelines concerning the bald eagle include restrictions on possibly hazardous conditions such as residential and industrial development projects, power lines, toxic chemicals, and logging (TPWD and USFWS 1993 and USFWS 1987b) within primary (750 to 1500 feet) and secondary zones (1500 to 5280 feet) around nests.

Like the bald eagle, swallow-tailed kites are probably not highly dependent upon BLHF as a habitat requirement. They tend to prefer a mixture of swamp forests and marshes, feeding over open marshes and ponds while usually avoiding dry, upland areas (Hamel 1992). However, the associated wetlands may be valuable as swallow-tailed kite habitat (McMahan and Frye 1986). Kites also prefer mature trees for nesting areas.

Osprey are known to use East Texas in spring and fall migration, but sightings within BTNP have not been reported.

Two other raptors, the red-shouldered hawk and barred owl (*Strix varia*), are also known to bottomland hardwood forests and to BTNP. Both of these species are considered typical raptorial representatives of the bottomland hardwood community,

although neither of them is restricted to it. Oberholser (1974) indicated that the barred owl uses the same habitat nocturnally as the red-shouldered hawk uses during the day. Oberholser blames the decline in red-shouldered hawks on an increase in cleared land and reservoirs, since new lakes in the 1970s flooded 600,000 acres of bottomland habitat that had previously supported the hawks. Frentress (1986) suggests that the sensitivity of the red-shouldered hawk to changes in BLHF makes it a good indicator species for the stability of the forest.

Wild Turkeys

There are three subspecies of wild turkey (*Meleagris gallopavo*) in Texas: the Rio Grande turkey, the eastern wild turkey, and Merriam's turkey (Campo and Dickson 1990). Historically, the most common turkey in East Texas was the eastern wild turkey, but it was almost extirpated from the area by 1900. Restocking was first attempted in 1924, but those birds quickly disappeared (Campo and Dickson 1990). Later restocking efforts with pen-raised turkeys and other subspecies were unsuccessful and in 1987 release of pen-reared turkeys became illegal.

Restocking with wild-trapped eastern turkeys, mostly from other states, has been the only restocking method in use since 1979. From 1979 to 1986, nearly 200 eastern turkeys were released in 11 sites in 8 counties. From 1986 to 1990, 1233 were released in 83 areas in 24 counties. This program was funded by Texas Parks and Wildlife Department, Temple-Inland, Champion International, Kirby Forests Products, International Paper Company, and many other land owners. The only releases to date in BTNP occurred in the Big Sandy, Lance Rosier, and Turkey Creek Units in 1994 (personal communication, Ricky Maxey, BTNP Wildlife Specialist), totaling 45 turkeys.

According to Wharton *et al.* (1982), Kennedy (1977) found that the eastern wild turkey feeds and nests in bottomland hardwood forests. The Florida Game & Freshwater Fish Commission (1978) found that BLHF support greater turkey population densities than upland sites, supporting 1 turkey per 10 acres compared 1 turkey per 25 acres for uplands sites.

BTNP presently does not permit turkey hunting. According to Rickey Maxey, TPWD occasionally permits turkey hunting in east Texas in very limited areas, but not on a county-wide basis. This policy is evident in the 1993-1994 Texas Hunting Guide (TPWD 1993e) which describes a permit with a one gobbler limit for only a two week spring season in very restricted areas.

Management Considerations

Game

Hunting and trapping are allowed in designated areas of the BTNP under provisions of 36CFR 2.2 (wildlife protection), 36CFR1.6 (permits), and 36CFR (special regulations) as described in the BTNP Supervisor's Orders (Strahan *et al.* 1993). Hunting season for waterfowl extends from approximately October 1 to January 15 and is allowed in designated areas of the Beaumont Unit, Big Sandy Creek Unit, Beech Creek Unit, Jack Gore Baygall Unit, Neches Bottom Unit and Lance Rosier Unit. Hunting is prohibited within 500 feet of any roadway or major waterway (Strahan *et al.* 1993).

Hunting records obtained from BTNP include information about waterfowl only for the 1990-91 and 1991-92 hunting seasons. Harvest information is from the BTNP Hunter Harvest data (BTNP 1993) and was determined from returned surveys mailed to permitted hunters. In the 1990-91 hunting season, waterfowl were taken in Jack Gore Baygall (14), Beech Creek (1) and Lance Rosier (1) Units. All waterfowl in the 1991-92 season were taken in Jack Gore Baygall (22). In the 1992-93 season, waterfowl were taken from the Beaumont (9), Big Sandy (27), and Lance Rosier (33) Units. The species and sex of the waterfowl taken were not recorded. Non-deer game harvests from 1984 to 1993, including waterfowl, are summarized in Appendix C.

Fragmentation

The transformation of forested wetlands into agricultural lands is a serious problem in many parts of the Southern United States. Childers and Gosselink (1990) estimate that only 30 percent of the pre-settlement forested wetlands remain today. The Big Thicket, which historically covered approximately 3.5 million acres is now only 300,000 acres, with 84,550 acres protected as a part of BTNP. Andrén (1994) found that total area of suitable habitat in a landscape was generally more important for species survival than the spatial arrangement of the habitat for landscapes with more than 30 percent of suitable habitat remaining. However, as the proportion of suitable habitat is reduced, the configuration of the habitat and the suitability of surrounding habitat become more important. With only less than 10 percent of the historical Big Thicket remaining, habitat fragmentation is a serious concern in BTNP.

Many recent studies have focused on the effects of forest fragmentation on bird populations, particularly neotropical migrants. Fragmented forest provides only marginal habitat for some songbirds because of possibly higher rates of nest predation and brood parasitism (Gates and Gysell 1978 and Wilcove 1985). Rates of nest predation by

American crows (*Corvus brachyrhynchos*) and blue jays (*Cyanocitta cristata*) are known to be higher in forest edge habitat (Harris 1988b).

Fragmentation appears to increase parasitism and decrease successful pairings in some species. Many of the birds Williams (1981) recorded, such as white-eyed vireo, Swainson's warbler, magnolia warbler (*Dendroica magnolia*), and eastern wood pewee, prefer dense areas away from the forest edge, and would likely be adversely affected by forest fragmentation. Gibbs and Faaborg (1990) attempted to determine to what degree the ovenbird and the Kentucky warbler were sensitive to the size of the fragment of forest in which they breed. In smaller fragments of 9 to 140 ha, they found that male ovenbirds were much less likely to be in a mating pair. The female ovenbirds appear to prefer contiguous forests.

The brown-headed cowbird (*Molothrus ater*), a brood parasite present in BTNP (Deuel and Fisher 1977 and Williams 1981), lays its eggs in the nests of passerine open-nesting birds, causing the unsuspecting parents raise the cowbird as their own. Adult cowbirds often destroy the eggs of the host parents, although sometimes the brood is either shoved out of the nest by the baby cowbird or starves to death, unable to successfully compete with the larger nestling (Brittingham and Temple 1983). Cowbirds are known to search preferentially for nests in areas of habitat discontinuity (Wilcove 1985). The rate of cowbird parasitism is much lower in the forest interior than at the forest edge, as is the predation rate (Gates and Gysell 1978, Brittingham and Temple 1983).

Interestingly, Hamel (1989) found that Swainson's and hooded warblers reached highest densities in selectively cut forests, although both species are known to nest primarily in thick undergrowth. In addition, white-eyed vireo, common yellowthroat, yellow-breasted chat, and indigo bunting reached highest densities in clearcuts. The differences in avian community characteristics found by Hamel are mostly quantitative and not qualitative. The same species were found in areas subjected to different silviculture regimes, but the relative densities of the species varied.

Maurer and Heywood (1993) examined the effects of forest fragmentation on abundance of neotropical migratory birds in North American breeding grounds. They found that neotropical migrant populations were more negatively affected by forest fragmentation and habitat loss than were resident species. However, they stressed that recent decline in neotropical migrant populations is due to the cumulative effects of a multitude of factors, including habitat loss and fragmentation in both the North American breeding grounds and in neotropical habitats.

Timber and Related Issues

The logging of forested wetlands has dramatically reduced the area of BLHF in parts of the Southern United States. Areas such as the Tensas River basin in Louisiana were once nearly all bottomland hardwood forest until the area was intensively developed for agricultural purposes. Now forest only covers 18 percent of the watershed area. Burdick *et al.* (1989), in an analysis of the Christmas bird counts before and after the deforestation in the Tensas River Basin, estimated that one species will become extinct every 44 years, even if no further forest loss occurs. However, Burdick claimed that by insuring the conservation of required habitats, a cumulative impact management plan could reduce further extinctions within this watershed. A cumulative impact management plan considers the cumulative impact of timber cuts and developments in natural areas rather than considering the impact of each proposal independently.

Another important management consideration is the fate of dead trees, or "snags." Snags provide nesting sites and roosts for woodpeckers, wood ducks, and hawks (Howard and Allen 1989). In many forests, they are removed for fire prevention or aesthetic reasons, but they are an important part of the ecosystem and should be maintained. Bats, raccoons, and opossums also utilize snags for shelter (Howard and Allen 1989).

A reduction in oak mast is another important impact of logging. Oaks do not produce acorns until they reach large size classes, so logged oak forests will not provide the mast required to support many birds, particularly waterfowl, that depend on oak mast for food.

Deer and Small Mammal Impact

Species such as white-tailed deer can have a profound effect on other species within the ecosystem. Harris (1988b) reports that the biggest limiting factor on the population size of the Kentucky warbler is the white-tailed deer, rather than cowbird parasitism or snake and small mammal predation. When their population grows large enough, white-tailed deer browsing alters the understory vegetation significantly. Significant increases in populations of raccoons and opossums also increase nest predation rates. Though there is no current evidence of problems in BTNP, the impact of these other species should be considered in the management of bird populations.

Endangered Species

Endangered species present in BTNP are listed in Appendix A. Bachman's sparrow (*Aimophila aestivalis*) is being considered for federal listing and is threatened in Texas (TPWD 1991). State listed as threatened, the wood stork (*Mycteria americana*) uses bottomland hardwood forests occasionally (Ernst and Brown 1988) and has been

sighted in BTNP, according to the sightings catalog in the library at the BTNP Beaumont office. The ivory-billed woodpecker (*Campephilus principalis*) is restricted to bottomland hardwood habitat. However, the bird has not been sighted in Texas in several decades and is believed to be extinct (Oberholser 1974, Frentress 1986). The red-cockaded woodpecker (*Picoides borealis*) is found in BTNP but is not usually associated with bottomland hardwood forests, since it nests in pines (Conner *et al.* 1991). The red-cockaded woodpecker is listed as endangered at both federal and state levels. As noted before, Bachman's warbler used forested swamps for habitat, but has not been sighted in Texas in several decades and is believed extinct (Peterson 1967).

Corridor Use

While the use of corridors by birds in BTNP have not been studied, birds in other parts of the world are known to use migration corridors. Saunders and de Rebeira (1991) studied the movement of birds through corridors in a fragmented landscape in Western Australia using mist netting and banding, as well as observations. They concluded that some species will use vegetated corridors, as narrow as 4 m wide, to move between areas. Saunders and de Rebeira also noted that wider corridors, provided they are well-vegetated, will be used for movement and breeding habitat more than narrower corridors. They emphasized that not every species benefits from movement corridors, but their study provides evidence that some species do use them.

Croonquist and Brooks (1993) studied riparian corridor habitat in forested watersheds in central Pennsylvania. They found that bird species richness and abundance generally decreased with distance from water corridors in partially disturbed agricultural or residential areas. By contrast, in undisturbed habitat in the same region, bird species richness and abundance was unaffected by distance from streamside. Catterall, Green, and Jones (1991) found that the edge effect on avifauna extended 15 m from the edge of the forest. They thus concluded that corridors 30 m wide would be dominated by birds that are edge-specific rather than forest-interior birds.

Corridor widths will influence species differently; few generalizations can be made. However, to accommodate forest-interior birds and keep rates of brood parasitism and predation down, wide buffer zones are needed to prevent the streamside from becoming a long, continuous edge zone. The extent that water corridors of BTNP are used by birds for movement between units is unknown.

Case Studies: Barred Owl and Wood Duck

Barred owls are traditionally associated with mixed woodlands, boreal forest, mixed transitional forest, and deciduous forest (Allen 1987). General habitat requirements for this raptor include large forested areas with mature trees large enough for cavities suitable for reproduction and security. Owl dietary needs vary regionally. In drier sites, they feed mainly on small mammals such as mice, voles, rats, and shrews (Devereux and Mosher 1984). A study in Mississippi suggests that in wetter sites, the birds may depend more heavily on crayfish in their diets (Allen 1987).

Devereux and Mosher (1984) suggested that barred owls may be more abundant in forested wetlands because of the relative inaccessibility of these lands to timber harvesting. They also suggested that very wet areas tend to have more mature and old-growth forests and that the larger trees of these areas attract and support larger barred owl populations. Hamel *et al.* (1982) identified forested wetlands and bottomland hardwood forests as the primary reproductive habitat of the barred owl in the Southern Coastal Plain region, which includes BTNP.

Wood ducks need cavities in trees to nest in, zooplankton to feed the young, and a food supply for the adults in shallow water (Patrick *et al.* 1981). Wood ducks are known to be permanent residents of Big Thicket (Deuel and Fisher 1977). Deuel and Fisher (1977) recorded the presence of seven wood ducks on their canoe census. Four wood ducks were observed on a foot census in loblolly pine-hardwood forest as well. A 1984 wood duck survey observed seven wood ducks, all in bottomland hardwood habitat (Healy 1984). In 1981, USFWS personnel observed approximately 100 wood ducks, most occurring in pairs and many with ducklings, in the Pine Island Bayou between State Highway 105 and U.S. Highway 69 bridges (Halstead 1981).

Water flow and water quality may affect the prey source for these birds. Maintaining snags for the endangered red-cockaded woodpecker would also provide cavities in trees for the wood duck and the barred owl to nest in.

Recommendations:

1) Studies should be undertaken to determine if the corridors are used as habitat and by which birds, and more specifically, to determine if they are used as movement corridors. Additional study of the use of BTNP corridors by migrating waterfowl or neotropical migrant songbirds is especially necessary.
2) Bird populations should be surveyed more frequently. The last survey in BTNP was performed in 1977. Determining if populations are increasing or declining is impossible if regular surveys are not taken. Christmas bird counts for the units of BTNP, such as currently being taken in the Turkey Creek Unit, would be useful, especially for the units with water corridors.

MAMMALS

Fritzel (1988) defined wetland mammals as "terrestrial or semi-aquatic mammalian species that commonly use wetlands for cover or obtain a major portion of their diet from wetland-dependent organisms." With the exception of animals such as the muskrat, swamp rabbit, beaver, or river otter, most mammals are not obligatory inhabitants of wetland habitats, though many use the habitat facultatively.

McMahan *et al.* (1986) reported that a total of 45 mammal species occur in BLHF of the southeastern United States. Of these 45 species, Schmidly, Barnette, and Read (1979) observed or collected 33, or about 73 percent, in BTNP. Their methods included the use of Sherman live traps, Victor rat traps, and Museum Special traps. Trap lines consisted of 50 stations, which were placed in areas the researchers selected for potential success, such as around fallen logs, stumps or leaf litter. Macabee gopher traps were used to collect gophers and Victor mole traps to collect moles whenever there were signs of activity in the area. Raccoons, skunks, and opossums were collected by leghold traps, Tomahawk live traps, and by shooting. Rabbits, squirrels, armadillos and other medium-sized mammals were shot opportunistically. The researchers also used road-kill animals whenever possible. Squirrel were counted by a stationary observer recording the number of squirrels seen within a semicircular plot within a given amount of time. Deer were counted by crossing transects: each evening, half-mile segments of sandy roads were smoothed and the next morning mammal crossings were identified and recorded.

Three major habitats were identified based on faunal similarity: disturbed habitat, flatland forest, and slope and floodplain forest. The third habitat corresponds to the bottomland hardwood forest found along the river corridors. No systematic surveys have been completed since 1979.

Small mammals

Species of Class Rodentia found in BTNP bottomlands include ten species of mice, four species of rats, three species of squirrels, a gopher, a vole. Two shrews and a mole, all of Class Insectivora, were also found. All of these species are facultative users of BLHF. Many require litter cover on the ground for habitat or food and since the intermittent flooding of the bottomland hardwood habitat washes away much of the ground litter (Wharton *et al.* 1982), BLHF is not a prime habitat.

The distribution of small mammal species seemed to correspond to the habitat types described by Schmidly *et al.* (1979), with each habitat type supporting different

species. However, the small mammals did not seem to separate into the upper, mid, and lower slope communities that correspond to the vegetation gradients outlined by Marks and Harcombe (1981). This lack of separation is probably due to the greater dependence on soil moisture availability of plants compared to mammals (Schmidly *et al.* 1979).

Gray squirrels (*Sciurus carolinensis*) show some preference for lowland habitat (Schmidly *et al.* 1979 and Davis 1974) and for the big hardwood timber near the rivers and large creeks of the bottomland hardwood forests (Schmidly 1983), especially in managed conifer or agricultural landscapes (Harris 1988a). Squirrel density was highest in stream floodplain forest and species composition differed between uplands and lowlands (Schmidly *et al.* 1979). Squirrels may be obligate users of bottomland hardwoods during the winter for food. The sandy ridges, or hammocks, that are often found in bottomlands provide optimal habitat for gray squirrels. The mixture of several species of trees in hammocks provides squirrels with food for all seasons and with dens for shelter and breeding (Schmidly 1983). Both fox squirrels and gray squirrels are common in BTNP and are hunted as game animals (see Appendix C for details on harvests).

Bats

The most common bats captured were evening bat (*Nycticeius humeralis*), seminole bat (*Lasiurus seminolus*), and red bat (*Lasiurus borealis*). Bat collecting activities were concentrated near water, either over streams or where intermittent streams and ponds tended to form. This concentration of collection activities skewed the sample, favoring those bats which roosted in the bottomland hardwood community.

The general habitat requirements of the bats of the BTNP are not well known. Bats are known to roost beside water and streams, but whether they live and feed in the bottomland hardwood forest or just prefer the roosting sites there is unclear (Schmidly *et al.* 1979). Most of the bats found in BTNP are migratory. However, studies to determine which migratory species breed in BTNP, an important management consideration, have not been conducted. Studies to determine whether the bats of BTNP utilize water corridors for movement or migration purposes also have not been conducted.

The northern yellow bat (*Lasiurus intermedius*) is rare in Texas, but it is known in the southernmost part of BTNP. This bat has an unusual habitat requirement: it roosts and bears its young in Spanish moss (*Tillandsia usneoides*) (Schmidly *et al.* 1979).

Large mammals

Large mammals that are known to be facultative inhabitants of bottomland hardwood forests in BTNP include opossum (*Didelphis virginiana*); nine-banded armadillo (*Dasypus novemcinctus*); black-tailed jack rabbit and eastern cottontail (*Lepus californicus, Sylvilagus floridanus*); coyote (*Canis latrans*); gray and red fox (*Urocyon cinereoargenteus, Vulpes vulpes*); raccoon (*Procyon lotor*); ringtail (*Bassariscus astutus*); Big Thicket hog-nosed skunk, striped skunk, and eastern spotted skunk (*Conepatus mesoleucus temalestes, Mephitis mephitis, Spilogale putorius*); white-tailed deer (*Odocoileus virginianus*); and feral hog (*Sus scrofa*). Large mammals that are known to be obligate inhabitants of bottomland hardwood forests in BTNP include swamp rabbit (*Sylvilagus aquaticus*); muskrat (*Ondatra zibethicus*); beaver (*Castor canadensis*); nutria (*Myocastor coypus*); river otter (*Lutra canadensis*); and mink (*Mustela vison*). Other large mammals, such as bobcat (*Lynx rufus*), are known to occur in BTNP, but were not encountered by Schmidly *et al.* (1979). Mountain lion (*Felis concolor)* was not found in the area and is assumed to be extremely rare or extinct in east Texas.

Schmidly *et al.* (1979) did not encounter beaver, but reported recent cuttings and beaver tracks. As demand for their pelts and the land occupied by their ponds grew, beaver were extirpated from the state in the early 1900's, only to be reintroduced through the 1940's and 1950's. Although beaver numbers were thought to be declining in 1978, Frentress (1986) reported that beaver were prospering throughout stream courses in East Texas in 1985 and had reached nuisance levels in some areas. Beaver have considerable impact on the landscape by damming streams. The ponds have a positive effect on some wildlife, such as waterfowl and river otter, but the flooding associated with damming can cause the death of canopy trees. Beaver also selectively cut certain tree species, which might otherwise be valuable timber (Schmidly 1983). Beavers require a year-round water supply and a renewable woody food source. Black willow, cottonwood, river birch, buttonbush, and water elm are often used food sources (Schmidly 1983); sweetgum is the most frequently used species in BTNP, however (Harcombe, personal communication).

Schmidly (1983) also reports that both mink and river otter require slack water habitats, which are provided by bottomland hardwood forests. Otter are thought to be increasing in number "possibly as a result of the prosperity of beaver populations in East Texas" (Frentress 1986). The ponds created by beaver damming help to stabilize local fish populations and also increase hunting grounds for otter. By 1977, river otter had

reoccupied most of its historical habitat; trapping activity does not appear to have threatened river otter populations. River otter are likely to be found in all units of BTNP except perhaps Beech Creek, Big Sandy, Hickory Creek Savannah, and Loblolly, and are probably most abundant in Neches Bottoms/Jack Gore Baygall, Beaumont, and Pine Island Bayou Units (Schmidly *et al.* 1979).

As carnivores, otters may have been negatively affected by the bioaccumulation of environmental contaminants such as pesticides and industrial wastes (McMahan and Frye 1986). More specifically, Wren (1991) noted that otter are very likely to suffer serious effects from aquatic pollutants due to their piscivorous nature. Foley *et al.* (1988) found that bioaccumulation of pollutants occurs in otter populations exposed to aquatic contaminants such as poly-chlorinated biphenyls (PCBs) and mercury that are present in the waters of the New York state study area. However, the current stability of BTNP otter populations may indicate that pollution is not a strong negative influence on present populations.

Swamp rabbits are common in all wooded bottomland regions of East Texas. They are also found in the heavy growth of grasses in marshes and along canals. They are abundant in BTNP, particularly in bottomland hardwood forests. "Wet lower slopes to large bottoms having shrubs for cover and sedges and grasses for food comprise optimal swamp rabbit habitats" (Schmidly *et al.* 1979). Korte and Fredrickson (1977) demonstrated dependence of swamp rabbits upon bottomland hardwood forests by showing the decline of the numbers of rabbits concomitant with the decline of the bottomland hardwoods in Missouri. However, McMahan and Frye (1986) suggested that the development of thicketed and dense herbaceous regrowth in post-clearing landscapes would suffice for the maintenance or possibly an increase in swamp rabbit populations. Swamp rabbits are an important food source for large predators and are therefore important in the trophic dynamics of the BLHF ecosystem.

Coyotes are generalists that exist in many different habitats in BTNP, including bottomland hardwood habitat. They are not limited to it, however. Coyotes have only moved into BTNP within the last century. Their range has expanded probably as a result of environmental disturbance by human activity (Schmidly *et al.* 1979). Coyotes can hybridize with the red wolf (*Canis rufus*), which once existed in BTNP but is now considered extinct because most living individuals contain a vast amount of coyote genetic material (Harris 1988b and Wayne and Jenks 1991).

Bobcats are known to be locally common throughout the timbered regions of East Texas and have been trapped and sighted in BTNP. They prefer heavily wooded uplands and bottomland forests, especially those with significant underbrush (Schmidly 1983),

but also are known to survive in prairies and semi-open farmland. Destruction of bottomland hardwood forest would probably be detrimental to the species, but it is believed that they would survive elsewhere (Frentress 1986).

Although bobcats are not classified as a furbearer in Texas, the number of pelts tagged in the state of Texas has consistently been more than 16,000 (McMahan and Frye 1986). According to BTNP trapping data for 1977-78, 16 bobcats per year were trapped within the preserve during this period. Current trapping information and population surveys are unavailable.

Cougars are also facultative inhabitants of bottomland hardwood forests in the BTNP region. McMahan and Frye (1986) stated that cougars have two habitat requirements: an abundance of deer for diet and seclusion from hunting and human influence. In the early 1950's, cougars were persistently reported in oak-hickory forest in Leon and Brazos counties (Schmidly *et al.* 1979). Whether cougars are present within the bounds of BTNP today is not clear. While the deer population in BTNP is theoretically sufficient to sustain a mountain lion population, deer hunting has caused and likely will continue to cause the decline of mountain lions in east Texas (McMahan and Frye 1986), including BTNP. Diamond (1993), using telemetry to track cougars in the Santa Ana mountains near Los Angeles, found that cougars can find and efficiently use water corridors for movement through natural areas. However, the extent of corridor use by mountain lions is not fully understood and it is not known if the water corridors of BTNP could be used by mountain lions as routes between the units of the park.

Management Considerations

Game

Hunting and trapping are allowed in designated areas of BTNP under provisions of 36CFR 2.2 (wildlife protection), 36CFR1.6 (permits), and 36CFR (special regulations) as described in the BTNP Supervisor's Orders (Strahan *et al.* 1993). Permitted hunters are allowed to take white-tailed deer, squirrel, rabbit, feral hog, and waterfowl. A limited number of permits are given out each year for the Beaumont Unit, Big Sandy Creek Unit, Beech Creek Unit, Jack Gore Baygall Unit, Neches Bottom Unit, and Lance Rosier Unit. Hunting is not allowed in the river corridors and is not permitted within 500 feet of any roadway or major waterway.

White-tailed deer are found in nearly all suitably brushy or wooded areas all over the state of Texas. They are known to eat twigs, shrubs, fungi, acorns, and grass and herbs in season (Burt 1964). According to the Florida Game and Freshwater Fish

Commission (1982), Stransky (1969) found that deer are more numerous in BLHF than in any other southeastern forest type. Schmidly (1983) describes bottomland hardwoods as one of the best habitats for deer.

The pattern and distribution of vegetation in an area determines the occurrence and abundance of deer because the deer preferentially browse the borders and edges of stands. Harris (1988a) found that species such as white-tailed deer are favored by the edges and openings created by roads, powerlines, and clearcuts. While they prefer forests or dense underbrush, deer can survive in a variety of habitats and are known on the coastal prairies. However, deer habitat quality has been declining due to cattle ranges, agricultural activity, and human habitation (Schmidly 1983).

Rogers and Schmidly (1978) performed a preliminary study in 1977 to determine whether hunting should be recommended for the Beech Creek and Big Sandy Units. They found that deer were much less abundant in BTNP than was suggested by the Texas Parks and Wildlife Department census data. They attributed the difference in abundance to collection of TPWD data from areas of early successional vegetation, in which the densities of deer were known to be high. Rogers and Schmidly also found the densities of deer to be higher in brushy areas as well. TWPD survey methods included Hahn cruise surveys, spotlight surveys, evening mobile surveys, and aerial surveys (Karns 1993).

The only current method of monitoring deer populations within the BTNP is through analysis of hunting permit and harvest data (Paul Whitefield, BTNP, personal communication). A comparison of BTNP and TPWD harvest and survey data from the surrounding area shows no evident trends for the last several years (Appendix B). BTNP hunter success rates are substantially lower than those calculated by TPWD. These lower success rates might reflect lower deer population densities within the preserve than expected by TPWD, but lower hunter success could also be the result of other preserve-specific factors. For example, road access to the preserve is limited, shooting from vehicles is not allowed, guns may not be loaded while in boats, there are no permanent stands, and there are no feeders (Paul Whitefield, personal communication).

Swamp rabbits are hunted locally for food. They are listed as game in the 1993-94 Hunting Regulations by BTNP. Harvest data for swamp rabbits is included in Appendix C.

Schmidly *et al.* (1979) reviewed the TPWD trapper survey from the 1976-77 trapping season, which was distributed to randomly selected licensed trappers in Texas. The following animals were most frequently trapped for fur in the counties containing BTNP units: raccoon, opossum, gray fox, red fox, bobcat, coyote, striped skunk, spotted

skunk, beaver, nutria, muskrat, mink, ringtail, and river otter. Raccoons and opossums are taken more frequently because they are the most abundant and easiest to trap.

The removal of large carnivores combined with habitat fragmentation and other factors has benefited scavengers like raccoons and opossums. Unnaturally high populations of raccoons and opossums can pose several threats to the management of the area. They are a nuisance to human populations and can be associated with health risks such as rabies, but they also prey on the ground nests of birds and reptiles in the area. Harris (1988a) noted that "about 200 species of native Florida vertebrates nest on or near the ground surface may be jeopardized because of overly high populations of these nest predators that were formerly kept in check." Harris lists the reduction in trapping of opossums and raccoons as an important factor in their population increases.

Currently, a limited number of trapping permits are given out for the Beaumont Unit, Jack Gore Baygall Unit, Lance Rosier Unit, and Neches Bottom Unit. The BTNP trapping harvest summary for 1992-93 showed that raccoons and possums were trapped more than any other animals, followed by mink, fox, and nutria. These results are similar to the 1991-92 results, but differ slightly from the results of the 1976-77 TPWD fur trapping survey. A total of 163 animals were taken in BTNP during the two trapping seasons (BTNP 1993a and 1993b).

Hunting and trapping harvests in BTNP (Appendix B and C) from the last decade and TPWD data for the area (TPWD 1993a, Boydston 1993, and Karns 1993) show no evident trends in total harvest for any game species. Because hunting harvests are relatively constant, population densities of game animals are probably not changing. Unless hunting or trapping harvests change, more rigorous monitoring of population densities is probably not necessary.

Timber and Related Issues

Logging and reforesting activities seem to have a negative impact on some BTNP mammal species. Schmidly *et al.* (1979) noticed a strong separation of small mammal species based on habitat disturbance. Areas that had been clear-cut and replanted with pine had different and fewer species than the non-disturbed habitats. Mammals such as southern short-tailed shrew (*Blarina carolinensis*) and golden mouse (*Ochrotomys nuttali*) are not found in clear-cut or disturbed areas. Increased presence of cotton rats (*Sigmodon hispidus*) and fulvous harvest mice (*Reithrodontomys fulvescens*) in logged areas reduces the number of other small mammal species in those areas. Logging may negatively affect small mammal diversity on land adjacent to BTNP. This impact may affect which small mammal species are seen in BTNP corridor units.

Like the avifauna, many mammal species depend on snags for shelter or as food sources. Big brown bats, raccoons, squirrels and flying squirrels, and opossums are all cavity-dwellers that utilize snags for protection (Howard and Allen 1989 and Frentress 1986). Frentress suggests that lack of snags may be a limiting factor in flying squirrel populations. Lower slope forest that had been previously cut had no squirrels at all, compared to 150 squirrels per 100 acres in virgin lowland floodplain forest. Squirrels need a closed canopy to facilitate movement around the habitat. Without a closed canopy, normal activity is disrupted and squirrels move elsewhere (Schmidly *et al*. 1979). If logging practices in adjacent land reduces the abundance of snags, presence of these species in BTNP may be reduced. For these reasons, uneven-aged timber management may be the best option if management goals included concern for bat, squirrel, raccoon, or opossum populations.

However, at least one mammal species present in BTNP may not be negatively affected by clearcutting. Though white-tailed deer populations are adversely affected by clearcutting, even-aged management, and pine plantations, there is evidence that deer populations are higher in areas that have been overgrown by shrubs after clearcutting: deer tend to prefer areas of dense undergrowth (Schmidly *et al.* 1979, Harris 1989). Thus, deer populations in logged areas could increase after understory shrubs have recovered.

Introduced Species

Introduced species in the area include nutria, feral cat, feral dog, and feral hog. All of these species were encountered by Schmidly *et al.* (1979). Feral dogs are known to be able to interbreed with coyotes and red wolves. Track count surveys in BTNP during 1981 indicate that the number of feral dogs was higher than the number of several native mammals. Also, several instances of dogs chasing white-tailed deer were recorded (Schmidly 1983). Feral cats do not hybridize with native cats. However, they do a great deal of damage to populations of songbirds, small rodents, and small reptiles. The contents of the stomachs of 33 feral cats in East Central Texas included, in decreasing order of abundance, the following prey: insects, cotton rats, cottontails, house mice, hispid pocket mice, deer mice, domestic chickens, bobwhite quail, red-winged blackbirds, rough green snakes, fence lizards, race runners, and little brown skinks (Parmalee 1953). Wild hogs are known to eat fruit, grass, mushrooms, roots, and invertebrates. Their habit of rooting in the soil can cause disturbances to the vegetation and soil in the vicinity. They also may compete with native animals for food sources, particularly mast (Schmidly 1983).

Indicator Species

Indicator species have been used for decades to gauge the habitat quality of ecosystems and as a measure of population trends in other species. However, the use of vertebrate indicator species has been questioned due to the lack of well-defined conventions and guidelines (Landres *et al.* 1988). A number of factors, such as population size and stability, life history, area requirements, and species specialization contribute to the variability of response of the indicator species. For instance, Dickson (1991) observed that the species that have continued to fare well in southern old-growth forests are generalist species such as white-tailed deer, while species with narrow niches or low reproductive rates have not faired as well in the face of habitat disturbance. However, due to easier access to accurate population studies, avian and mammalian species are often chosen as indicator species (Croonquist & Brooks 1991).

Croonquist and Brooks (1991) account for this variability of response by classifying species into an array of response guilds based on their susceptibility to habitat disturbance on the landscape level. They found that, when examined specifically for effect on species within the same response guild, both mammalian and avian species were useful indicator species for analysis of changes in the functional characteristics of wildlife communities in response to environmental changes that occur subtly but cumulatively. However, Croonquist and Brooks stressed the importance of accurate response-guild groupings and the use of multiple indicator species in order to achieve a whole-system view.

Indicator species have not been formally used within the BTNP to gauge habitat quality. To establish an appropriate indicator species for BTNP, more comprehensive studies of population size, habitat usage and residency status would have to be completed.

Endangered Species

Endangered, threatened, and candidate species in the Big Thicket area are listed in Appendix A. Two species of bats found in BTNP are listed as threatened in the state of Texas and are being considered for federal protection: the southeastern bat (*Myotis austroriparius*) and Rafinesque's big-eared bat (*Plecotus rafinesquii*). Additionally, the red wolf is also listed as endangered both federally and in Texas, but is believed to be extinct in the wild.

Black bears (*Ursus americanus*) are also facultative inhabitants of bottomland hardwood forests. Black bears are known to use forest and water corridors to facilitate movement in fragmented habitat (USFWS 1994). They can travel upwards of 20 miles in

a night and will use corridors that are as narrow as 50 meters wide for movement (Sean Willis, TPWD, personal communication). Black bears probably inhabited BLHF and river corridors in BTNP due to the diversity of food resources and seclusion that the corridors offered (McMahan and Frye 1986).

The black bear is currently classified as endangered in Texas, Louisiana, and Mississippi. Louisiana black bears, a subspecies of the American black bear, were historically present in East Texas, but were reduced to relic populations in the early 1900's and became extinct in the area in the 1930's (Baker 1956). From 1964 to 1967, however, American black bears from Minnesota were released in the Atchafalaya Basin in Louisiana as a restocking effort (Schmidly *et al.* 1979). The black bear population in the Atchafalaya and Tensas River Valleys is now estimated to be around 300 individuals . Estimated date for removing the Louisiana black bear from the endangered species list is 2025.

Black bears have not been sighted in BTNP in more than 20 years, but descendants of bears released in Louisiana are dispersing and expanding their range west from the Atchafalaya Basin to Lake Charles and have been sighted as far west as Jasper County (Rickey Maxey, BTNP biologist, personal communication). The Texas Parks and Wildlife Department has been investigating possible black bear habitat in the Big Thicket area of East Texas (Sean Willis, TPWD, personal communication). Viable habitat for black bears requires a contiguous 50,000 acre area with necessary hard mast for autumn food, fruits and berries for summer food, den trees, escape and protection cover, and low human population and road density. Primary areas under investigation for possible black bear habitat include the Lance Rosier Unit, the Jack Gore Baygall Unit, the Big Sandy Unit, and surrounding private timber land owned by Louisiana Pacific and Temple Inland (USFWS 1994).

Corridor Use

There is some evidence that small mammals use corridors for movement between fragmented habitats, though most were conducted on a smaller scale than is appropriate for BTNP. Bennett (1990) writes, "Evidence for the effectiveness of corridors in promoting continuity between isolated habitats is limited, and is largely restricted to studies involving small, closely-spaced patches of habitat in agricultural landscapes." Very little is known about corridor effectiveness on the scale of the BTNP, where corridors extend kilometers rather than meters.

In general, wider corridors decrease the risk of invasion from feral animals and thereby reduce predation. Vegetation invasion, which may alter habitat structure, is also a problem and may affect food resources and microhabitats of some of the smaller mammal species (Bennett 1990). Merriam and Lanoue (1990) measured the use of corridors (fencerows) between forest fragments by mice. They found that the mice did use the corridors and that there was a clear difference in the use of various qualities of corridors. The corridors that had a high amount of structural diversity (unlimited shrubs and structural elements, with trees on more than 10 percent of total length) were used at a much higher rate than the intermediate or simple corridors.

Narrow corridors are essentially long, continuous edge zones . The extent of the edge effect is a primary concern in corridor design. This edge increases the exposure of animals using the corridor to human contact, facilitating poaching and invasion by domestic animals. Since there are residential communities around the water corridor units of BTNP, use of the corridors for habitat by mammals could be interfered with by humans and domestic animals. Also, mammals such as Virginia white-tailed deer and bobcats tend to follow specific routes and these routes can be exploited by hunters and poachers (Simberloff and Cox 1987). Very little research has been done to establish minimum widths for corridors to facilitate use by animals.

Case Study: Nutria

Nutria is a representative case of a species introduction into BLHF. They were introduced into Southern Louisiana from South America in 1938 and spread into East Texas shortly thereafter. In 1946, nutria were released along the coast near Port Arthur to clear the aquatic plants out of lakes and farm ponds that were choked with vegetation (Schmidly 1983). Since introduction, they have become both an asset and a pest. They can clear aquatic vegetation and are harvested for their fur. However, they do great damage to dikes and levees and have been known to eat through entire rice fields (Schmidly 1983).

Nutria are very closely associated with waterways, and spend much of their time in the water. Their habitat needs include floating logs or dry ground with vegetation during the spring and summer for reproduction, bark for food during flooding, and herbaceous vegetation for food during non-flood periods (Patrick *et al.* 1981). Nutria have been trapped for their fur in BTNP, although they are not particularly sought out since the fur is not particularly valuable. Schmidly *et al.* (1979) stated that "undoubtedly, nutria occur along all major rivers and creeks which traverse the units of BTNP." Like

beaver and river otter, these mammals may use the rivers as migration and movement corridors.

In coastal marsh in Louisiana, Nynan *et al.* (1993) found a negative association between nutria density and plant species richness. Native muskrat density, however, was positively correlated with species richness. Dirzo (1984) explained these correlations through feeding habits: nutria feed on minor plants in the area while muskrats feed on the competitive dominant species. This negative impact on species diversity by nutria suggests that they may have a long term effect of reducing plant species richness and thereby altering the system in areas where they have been introduced.

However, the findings of Chabreck *et al.* (1981) contradict these predictions of reduced species richness resulting from nutria introduction. Chabreck *et al.* found that the diet for the nutria and the muskrat consist largely of the same species but in different proportions. If nutria and muskrat feed on the same dominant plants, the mechanism for the negative impact on species richness that Dirzo (1984) predicted is not clear. The impact of this direct interspecies competition on muskrats or nutria populations is not known. Also, whether nutria will have such an effect on species richness in the water corridors of the Big Thicket is unknown.

Recommendations:

1) Because the units of BTNP are spatially scattered, the water corridors may play an important role in maintaining the integrity of precarious populations such as the southeastern bat and Rafinesque's big-eared bat. Studies should be undertaken to quantify use of the corridors for habitat and for passage between units of fractured habitat.
2) The last comprehensive study of mammals present in BTNP was Schmidly, Barnette, and Read in 1979. A more up-to-date study of mammal diversity should be completed in order to provide an overall sense of the stability of historically present populations in BTNP. Ideally, this study should included aspects such as population size and density, habitat usage, and residency status, thus laying the groundwork for the use of indicator species to judge BTNP habitat quality.

REPTILES AND AMPHIBIANS

Although they sometimes occupy different habitats, reptiles and amphibians can overlap considerably within the food web and frequently share similar habitat needs. Since they are often lumped together in the literature, they will be considered together here. Five different groups of reptiles are present in BTNP: snakes, skinks, lizards, turtles, and alligators. Amphibians include salamanders, toads, and frogs.

Many species of both groups require both land and water during their life cycles and thus are dependent upon land-water interfaces. The interfaces found in the riparian systems and bottomland hardwood forests of BTNP provide an important habitat for reptiles and amphibians. Further, some evidence indicates that they use river corridors for migration purposes. Other reptile and amphibian species use riparian systems opportunistically, even if they are not obligate users.

Reptile and amphibian abundance can be remarkably high in riparian systems. For example, Burton and Likens (1975) estimated that in Hubbard Brook Experimental Forest in New Hampshire, the biomass of the salamanders was 1.6 times greater than the biomass of birds and was approximately equal to the biomass of mammals. Amphibians and reptiles can be the dominant predators in a system in terms of biomass (Brode and Bury 1984).

In addition to abundance in riparian areas, herpetofauna in the southeastern United States is exceptionally diverse. Hall (1994) compiled range maps from species known to inhabit the United States. He found that 50 percent of species in the United States are found in the southeastern quarter of the country. Hall's findings, combined with Burton and Likens's evidence of riparian abundance, indicate that the water corridors and other riparian areas of BTNP may be highly diverse in herpetofauna.

A fairly comprehensive study of the distribution and relative abundance of reptiles and amphibians in BTNP was performed in 1978 by Fisher and Rainwater. They completed two surveys, one in the summer (May 20-July 3, 1975) and one in the spring (March 10-May 25, 1976). They recorded 44 species and 1470 individuals by foot, 19 species and 145 individuals by car at night, and 14 species and 221 individuals by canoe on the major waterways (Neches River and Pine Island Bayou). The walking censuses were done systematically on foot by a single observer who recorded species and number of individuals encountered per hour and per mile. Car and canoe censuses were performed similarly. Accounting for overlap between the three survey techniques, a total of 53 species of reptiles and amphibians were observed. The reptiles and amphibians of BTNP have not been surveyed since the Fisher and Rainwater study.

The reptiles and amphibians Fisher and Rainwater found in BTNP are similar to the species that would be expected in a southeastern bottomland hardwood forest (Wharton *et al.* 1982). McMahan and Frye (1986) tabulated 31 species of amphibians and 54 species of reptiles that occur in BLHF. In their survey of BTNP herpetofauna, Fisher and Rainwater (1978) found 62 percent of the species that McMahan and Frye found in their survey of BLHF herpetofauna. Fisher and Rainwater found 16 of the 31 amphibian species and 37 of the 54 reptile species that McMahan and Frye found.

Fisher and Rainwater's study, particularly when considered with McMahan and Frey's results, indicates that BTNP contains an exceptionally large herpetofaunal diversity for an area of its size. In comparison, only 50 species were observed in the 1900 ha Patuxent Wildlife Research Center, Maryland, during 50 years of study (Hall 1994). Similarly, only 35 species were recorded in the 329 ha Fitch Natural History Reservation in Kansas after 35 years of intensive study. The 53 species of herpetofauna found in BTNP exceeds the number of herpetofauna species ever recorded in the state of Colorado.

Reptiles

Snakes

Snakes provide a good example of both facultative and obligate bottomland species. Some, like the black racer (*Coluber constrictor*) and the Texas rat snake (*Elaphe obsoleta*), occur in a wide range of habitats because they are indiscriminate feeders. They are found in the bottomland hardwood habitat, but they are not dependent upon it. Other snakes, such as the mud snake (*Farancia abacura*), are restricted to the lowlands of the southern United States, or prefer backwater sloughs, and depend on aquatic vertebrates such as salamanders and tadpoles for food (Fisher and Rainwater 1978).

Species of *Nerodia* (water snakes) also require permanent bodies of water and a land-water interface on which to bask. The water snakes prefer some ground cover under which to hide on the banks, but spend much of their time in the water searching for food (Fisher and Rainwater 1978). While they also utilize small upland streams, they appear to prefer lowlands because of increased availability of food.

Florida watersnake (*Natrix sipedon pictiventris*) moves to more favorable areas when ponds dry up and uses streams and rivers to migrate from one area to another (Holman and Hill 1961). Other species of aquatic snakes are also known to migrate (Gregory *et al.* 1987). These patterns of migration suggest that aquatic snakes may use the river corridors to move from one patch of habitat to another.

The four members of the Family Viperidae are found in BTNP: southern copperhead (*Agkistrodon contortrix*), western cottonmouth (*A. pisciverus*), timber rattlesnake (*Crotalus horridus*), and canebrake rattlesnake (*C. horridus atricaudatus*). These snakes are often found in lowland or bottomland habitats, but are not restricted to them. Copperheads are common throughout the preserve while cottonmouths are always found near water, where they obtain their food. Both of these snakes are common in BTNP; canebrake and timber rattlers rarer.

Turtles

Fisher and Rainwater found 12 species of turtles in their surveys of BTNP. These turtles represent four families: Kinosternidae (musk and mud turtles), Chelydridae (snapping turtles), Emydidae (semiaquatic pond and marsh turtles), and Trionychidae (soft-shelled turtles). Several members of the Chrysemys complex of turtles are represented in BTNP. The Chrysemys complex is a group of semiaquatic pond and marsh turtles in the Family Emydidae which includes members of the genera *Trachemys*, *Pseudemys*, and *Chrysemys*. The habitat use and natural history of this group have been well-studied. *Trachemys* and *Pseudemys* are represented in BTNP.

The slider (*Trachemys scripta*) is a good example of an aquatic turtle which is known to use bottomlands, rivers, ditches, sloughs, lakes, and ponds (Morreale and Gibbons 1986). The turtle requires quiet waters, one to two m in depth, vegetation cover, and basking sites (Cagle 1950). Like most of the Chrysemys turtles, they are omnivores. They prefer crustaceans, mollusks, adult and larval insects, tadpoles, frogs, and fish (Morreale and Gibbons 1986), but are also opportunistic carrion feeders. Sliders also feed on vegetation: filamentous algae, duckweed, and a wide variety of surface and submerged aquatic plants (Parmenter 1980). Population distributions are patchy and may follow algal blooms and aquatic macrophyte growth (Morreale and Gibbons 1986). The turtles mate in the water, but lay their eggs on land. Females seem to prefer egg-laying sites near water with loose soil; they have been known to travel several hundred meters over land to find a good site (Gibbons *et al.* 1990). Males have been recorded moving up to 5 km in the water; Morreale *et al.* (1984) found that they move between habitat patches in order to find females. Thus, slider turtles may use the river corridors for movement between the larger units of BTNP, as well as for habitat.

Lizards and Skinks

The lizards and skinks found in the river corridors of BTNP are generalists, found in many different units of BTNP (Fisher and Rainwater 1978). The habitat needs of lizards and skinks do not include running or standing water. Fisher and Rainwater (1978)

recorded only three species of lizards in bottomland hardwood forests; all were upland or dry-site lizards. However, they did not report several species that are well-known in the area (Rainwater 1974). The green anole (*Anolis carolinensis*) was seen in the Neches River corridor, but in general it prefers dry forests with a dense understory (Fisher and Rainwater 1978). Fisher and Rainwater also found the eastern fence lizard (*Sceloporus undulatus*) and the six-lined race runner (*Cnemidophorus sexlineatus*). The latter species generally avoids dense vegetation and was rarely encountered in BTNP.

Fisher and Rainwater also recorded only three species of skinks, all of which were associated with wetland habitats. However, all three require ground litter for cover and food and therefore are not found in floodplain areas where litter is regularly washed away. The ground skink (*Scincella lateralis*) and the five-lined skinks (*Eumecies fasciatus* and *E. inexpectatus*) are common (Wharton *et al.* 1982). The broad-headed skink (*Eumeces laticeps*) is more arboreal than the other two species and less common in East Texas (Fisher and Rainwater 1978).

Alligators

Alligators were placed under Federal protection in 1969. After protection, alligator populations exploded in number, resulting in removal of protection in 1972 (Newsom *et al.* 1987). Fisher and Rainwater did not encounter *Alligator mississippiensis*, which was then an endangered species. However, alligators have since been sighted in the Neches River in the Neches Bottom Unit (Rosine Hall, personal communication).

Alligators are well-adapted for marsh and swamplands, but they also occupy all other available aquatic habitats including, rivers, lakes, and tidal areas (Alcala and Dy-Liacco 1989). Juveniles feed mainly on insects, while adults are known to eat snakes, turtles, snails, fish, small mammals, birds, other alligators, and occasionally larger mammals including calves and dogs (Delany and Abercrombie 1986 and Rootes and Chabreck 1992). In north-central Florida, fish were the most important food for the alligator by percent volume, followed by crustaceans. However, alligators utilized a wide variety of food sources and took advantage of any local abundance of prey (Delany and Abercrombie 1986). Valentine *et al.* (1972) found similar results in the Sabine National Wildlife refuge in Louisiana. Alligators are known to attack humans on rare occasions, usually in a territorial defense. They spend the majority of their time in the water, but use logs and banks for basking. Females also lay their eggs on the shore.

Amphibians

Frogs and Toads

Many of the frogs and toads of BTNP are generalists and live in varied habitats. Toads such as the gulf coast toad (*Bufo valliceps*) are found in nearly every conceivable habitat (Fisher and Rainwater 1978). However, an important difference in the habitat needs of amphibians and reptiles is the dependence of amphibians on water, and thus riparian or wetland areas, at some point during their life cycles for reproduction (Brode and Bury 1984). A few amphibians require bottomland forest for their entire life cycle, but most depend on bottomland forest for only the early part of their lives and for reproduction. Some species, such as the green treefrog (*Hyla cinerea*) live in wooded swamps, lakes, and streams for all of their lives, while other species, such as the southern leopard frog (*Rana pipens*), return to the water less often, many times only to breed (Fisher and Rainwater 1978). The crawfish frog (*Rana areolata*) has an unusual habitat requirement: it spends its daylight hours in burrows or tunnels made by crawfish.

Salamanders

Salamanders in BTNP include the marbled salamander (*Ambystoma opacum*), the dwarf salamander (*Eurycea quadridigitata*), and the central newt (*Notophtalmus viridescens*) (Fisher and Rainwater 1978). Members of the mole salamander family (Ambystomatidae) utilize bottomlands and other habitats that have standing water during the parts of the year that the salamander requires water for its life-cycle. They spend their larval period in temporary ponds during the drying period in the summer. Adults migrate to the ponds in the autumn rainy season. The marbled salamander (*A. opacum*) then lays its eggs in depressions that will fill with water after the leaves fall in the autumn (Hairston 1987). The true salamanders (*Salamanderidae*), such as the central newt (*Notophtalmus viridescens*), generally have aquatic adult stages. Found in swamplands, wooded ponds, and river bottoms throughout the Southern U.S. (Fisher and Rainwater 1978), the central newt has three stages of its life cycle: the larval stage, the eft stage, and the adult stage. The first and last stages are aquatic, but the eft stage is terrestrial. In several areas of the coastal plains, the eft stage is sometimes omitted, possibly because the surrounding sandy habitats are inhospitable (Hairston 1987). Thus, populations of *N. viridescens* in BTNP may be aquatic their entire lives.

Management Considerations

Timber and Related Issues

Timber harvesting in riparian areas can have a negative impact on amphibian populations. Bury (1968) attributed the disappearance of the tailed frog (*Ascaphus truei*) to the removal of timber. Where timber had been removed by logging or fire, Bury found that the temperature of the water increased beyond the maximum survival temperature (22°C) for the larval stage of the frog. Brode and Bury (1984) also found that removal of shade around streams negatively influenced many species of salamanders. These studies were performed in a desert environment in California, however, where there is a marked difference between the riparian area and the arid desert environment. No similar study has been performed in a habitat similar to those found in BTNP.

Rudolph and Dickson (1990) tested the hypothesis that streamside buffer zone width affects amphibian and reptile communities. Their study was carried out in a mesic environment in East Texas, thus better approximating the habitats of BTNP. Higher abundance of reptiles and amphibians in riparian zones was correlated with a closed canopy and leaf litter ground cover. Rudolph and Dickson recommended streamside zones of at least 30 m or even wider when forest stands have been harvested. They hypothesized that narrow streamside zones did not have sufficient leaf litter accumulation to support reptile and amphibian communities and that the wider buffer zone would provide more extensive shading and litter composition. These two habitat elements are critical to the maintenance of herpetofauna populations.

Endangered Species

Endangered, threatened, and candidate reptile and amphibian species in the Big Thicket (Appendix A) include the Louisiana pine snake (*Pituophis melanoleucus ruthveni*), the Texas garter snake (*Thamnophis sirtalis annectens*), the timber or canebreak rattlesnake (*Crotalus horridus*), and the Texas horned lizard (*Phrynosoma cornutum*). All except the horned lizard are facultative inhabitants of bottomland hardwoods.

Amphibian Decline

Recent reports suggest that many amphibian species worldwide are undergoing population decline, range reduction, and even extinction (see Blaustein and Wake 1992). Whether observed declines in amphibian populations are the result of human actions or

natural fluctuations is not known due to the lack of long-term studies of amphibian populations. Human activity, such as habitat destruction and waterway acidification, is likely responsible for at least a portion of the observed population declines.

Amphibians are integral parts of many ecosystems: their contribution to trophic dynamics is of undeniable importance (Burton and Lichens 1975). Phillips (1990) asserts that amphibian populations, due to their position in the food chain, may provide an early indication that habitat destruction is threatening natural areas. However, amphibian populations are often more variable than those of other species; their population size and density tend to fluctuate more than those of other groups (Blaustein *et al.* 1994). Thus, without long-term studies of amphibians to determine the natural magnitude of their population fluctuations, determining whether changes in population size are due to human activities and whether population fluctuations threaten amphibians with extinction is difficult (Blaustien *et al* 1994).

Potential Impact of Recreation on Turtle Populations

Managing the water corridors of BTNP for turtle populations may require special consideration of the potential impact of human recreation. Garber and Burger (1995) studied the effects of human activity on two North American wood turtle populations (*Clemmys insculpta*) in a Connecticut preserve for 20 years. Both previously stable populations of turtles declined when the preserve was opened to hiking and fishing. Further, turtle populations remained stable when human access to the preserve was denied. Garber and Burger concluded that increased recreational use of the preserve had a negative effect on the wood turtle populations. While no similar study has been conducted in southeastern BLHF, the potential impact of recreation on turtle populations in BTNP should be considered. Areas of particular use by either of the two endangered turtles found in BTNP, the alligator snapping turtle (*Macroclemys temminicki*) and the Texas diamondback terrapin (*Malaclemys terrapin littoralis*), should receive special attention regarding the potential impact of human recreation.

Corridor Use

No studies have been conducted in this area to determine whether the corridors are being used by amphibians or reptiles for migration purposes. Species such as slider turtles or alligators could use the rivers to move from one area to another. Since turtles have been known to move 5 kilometers or more along rivers in search of mates (Morreale *et al.* 1984), they could use the rivers for migration during mating season.

Bottomland hardwood corridors may provide a mechanism for dispersal of some species of amphibians of BTNP, as well as important habitat. Amphibians generally have smaller home ranges and move smaller distances than do other small-bodied tetrapods such as rodents or lizards (Sinsch 1990), limiting their ability to recolonize areas that have been disturbed by human activities or natural disasters (Blaustein *et al.* 1992) or to respond to current disturbance. In their analysis of a riparian system in California, Brode and Bury (1984) concluded: "Amphibians and reptiles may be abundant in riparian systems where they can outnumber other taxa. Riparian systems provide important corridors of dispersal for many species. Disruption of these corridors can cause isolation and may lead to local extinctions." Due to their limited terrestrial movement and their physiological need for water, river corridors seem necessary to facilitate amphibian recolonization of disturbed areas (Blaustein *et al.* 1992). However, the potential role of water corridors in assisting amphibian recolonization is difficult to determine due to the lack of amphibian population studies in BTNP.

FISH

The fish communities in the streams and rivers of BTNP are reasonably well-known. Two comprehensive studies of the fish population have been conducted: Conner (1977) and Suttkus and Clemmer (1979). This report focuses mainly on Suttkus and Clemmer's report because it not only describes what the researchers found, but also compares it to the findings of an earlier study. TPWD surveys all of the 13 major river systems in Texas on a three to five year rotation (TPWD 1993f). More recent sampling was performed by TPWD in late 1995 (Paul Seidensticker, personal communication). Census data may be obtained from the TPWD Jasper office.

Suttkus and Clemmer (1979) sampled all of the BTNP units except the Loblolly Unit, which has no apparent flowing water, and the Neches Bottom/Jack Gore Baygall Unit, which was flooded when they attempted to sample there. Maps of sampling locations and the dates of the sampling were reported in the article. The fish were caught with a 10 by 6 foot nylon seine of 3/16" ace mesh. A total of 85 species and 151,999 specimens were collected in BTNP. Two additional species were recorded by Conner (1977), bringing the total to 87 fish species. In 1980-81, a TPWD census of fish in the Neches River and its tributaries between Steinhagen Dam and Sabine Lake found 78 species (1981 and 1982). In smaller tributaries, minnows, darters, sunfish, small bass, and bullhead catfish were the most abundant species. Larger tributaries were dominated by channel, blue and flathead catfish, sunfish, largemouth and spotted bass, and crappie.

Comparison of the data collected in these two studies suggests that stream flow and flooding conditions have a profound effect on the relative abundance of the fish, but do not change the species present. The relative abundance of the 1979 survey differed substantially from the 1977 survey, despite sampling the same sites, on the same dates, using the same procedures. However, the surveys were sampled at different water levels: the 1979 survey was performed during extremely high flood conditions.

Swift *et al.* (1986) compiled species diversity data from watersheds in the Southeastern United States. They found that a total of 241 freshwater fish species inhabited water between the Savannah River and Pontchartrain Lake. The average drainage had 57 species present. Only three drainage basins--Pearl, Mobile Bay, and Savannah--had more than 87 species present. These comparisons indicate that the waterways of BTNP, which contain 87 species, are a region of high freshwater fish species diversity.

Many of the fish that use the larger channels in the Mississippi River system move into the smaller streams in the spring for spawning; fish in BTNP are believed to migrate similarly (Suttkus and Clemmer 1979). During spring flooding, the backwaters of the bottomland hardwood forests are inundated with nutrients, creating concentrations of zooplankton as a food source. Early and prolonged flooding provides a continuous source of incoming food for the larval fish, reducing competition and allowing rapid growth (Wharton *et al.* 1981). Adult finfish and crawfish use the floodwater edge as habitat for spawning (Howard and Allen 1989).

Many of these backwaters along the water corridors of BTNP are not under protection. Wharton (1980) describes the bottomland hardwood habitat along the Altamaha River in southeast Georgia as a mosaic of habitats that are vital to one species or another: "The sloughs, ox-bows, tributaries and floodplain itself serve as spawning grounds and nurseries not only for fresh water fish but for many anadromous marine fish as well. Each species may use different habitats and different sections of the river for breeding and nursery functions." The pelagic spawners, such as drum (*Alodinotur* spp.), are some of the few fish that do not utilize the bottomland hardwood ecosystem at some point in their life cycle (Wharton *et al.* 1981). Based on the role of backwaters of the Altamaha River, the unprotected backwaters outside BTNP seem likely to be important habitat for the spawning of some freshwater fish species. The role of these unprotected waters warrants further study.

Water Quality

Different species require different environmental limits or parameters. For example, largemouth bass, which is generally considered a backwater fish, must have a dissolved oxygen content of at least 8 mg/l, a pH between 6.5 and 8.5, and turbidity between 5 and 25 ppm (Stuber *et al.* 1982). In contrast, redear sunfish, a more generalist species, is a bottom feeder and is tolerant of higher levels of salinity and lower dissolved oxygen levels than many more habitat-specific species. Redear sunfish require a pH range of 6.7 to 8.6 and a dissolved oxygen level of at least 1.5 mg/l in 25°C water, or 2.0 mg/l in 35°C water (Twomey *et al.* 1984). Many other southern game fish are also tolerant of a large range of temperatures and water quality parameters. Dissolved oxygen above 3 mg/l is considered adequate in general; above 4 mg/l is optimal for fish in bottomland hardwood areas (Hall and Lambou 1990).

Due to proximity to the Gulf of Mexico, saltwater intrusion is another potential problem. Historically, construction of temporary dams or saltwater barriers has been common practice (U.S. Dept. of the Army, Corps of Engineers 1994). A permanent barrier at river mile 23.0 of the Neches River has been proposed but not constructed, due to lack of funding. In the meantime, two temporary barriers have been approved for construction on the Lower Neches River, between mile 33.5 and 35.0, and in Pine Island Bayou at mile 3.0. These barriers are intended to improve upstream water quality. According to the Army Corps of Engineers (1994), Harrel (1975) documented dramatic differences across such barriers. Upstream of the barrier, dissolved oxygen was 8.2 ppm on the surface and 7.1 ppm on the bottom; downstream, dissolved oxygen was 3.4 and 0.0 on the surface and bottom, respectively. The upstream side also had lower turbidity, sulfates, and salinity and higher pH. The Lower Neches River Valley Authority and TPWD will monitor the effect of these barriers on paddlefish and freshwater mussels in a joint study (U.S. Dept. of the Army, Corps of Engineers, 1994).

Contamination by toxic substances is another potential threat to water quality. Toxic substances such as some pesticides, heavy metals, acids, brine, and oil can negatively affect spawning habitat and food availability (Hall and Lambou 1990). High industrial discharges and agricultural runoff combined can cause severe problems during spawning season if the silt settles on the newly spawned eggs (Howard and Allen 1989).

In 1986-87, as part of the National Bioaccumulation Study (NBS), the US EPA collected and analyzed several fish tissue samples from the Lower Neches River at Evadale, one-half mile downstream from the Temple-Eastex discharge canal. Some of these samples contained concentrations of the dioxin 2,3,7,8,-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) in excess of the 10^{-4} risk level. A description of the EPA's method of determining risk level appears in Bigler and Greene (1993). The EPA findings prompted the Texas Dept. of Health to issue a fish consumption advisory, which included the portion of the Lower Neches River Corridor Unit below U.S. Highway 96 and the Beaumont Unit (Texas Dept. of Health 1990). Although more recent samples show reduced concentrations of this toxin (Texas Dept. of Health 1994), the advisory is still in effect (Lisa Williams, Texas Dept. of Health toxicologist, personal communication). The Texas Dept. of Health continues to monitor the situation, but sampling is not performed on a regular basis due to limited funding (Gary Heideman, Texas Dept. of Health, personal communication).

the bank and preventing erosion. Removal of large woody debris which is anchored into the stream bed can have a profound effect on the channel stability of the stream and negatively affect the fish population.

Endangered Species: Paddlefish

Paddlefish (*Polydon spathula*) are listed as endangered by the state of Texas (TPWD 1991). Their range in the United States includes the Mississippi River basin and the adjacent Gulf Coast drainage, including the Neches River. Paddlefish generally inhabit large rivers, but have been known to inhabit reservoirs and natural lakes that are connected to large rivers (Hubert *et al.* 1984). Presence of paddlefish in the Lower Neches River was documented by Bounds *et al.* (1981) and Seidensticker (1994). While paddlefish are not dependent upon bottomland hardwood and backwater habitats, they benefit from and can be found in bottomland hardwoods. The waters of the corridor units are both habitat and migration routes for this species of fish.

Paddlefish spawn over gravel beds between late February and late June when water temperatures are 10 to 17° C. USGS data (cited in Pitman 1992a) from 1981-86 showed that the Lower Neches had acceptable temperatures from January to March for three out of six years. However, even with appropriate temperatures and substrate, only high and prolonged river flow (>275 m^3/s) will attract the fish to the appropriate gravel beds. Thus, the Lower Neches appears to be a marginal spawning area, having acceptable river flow only one year out of six between 1981 and 1986 and only for February. However, the backwaters of the Lower Neches can provide important summer feeding areas. While paddlefish use backwater during the summer months because of the abundant food supply, backwaters are not essential habitat for paddlefish. First year young (<120 mm) select individual large cladocerans to feed on, but larger individuals (>120 mm) filter feed on zooplankton and immature aquatic insects. Adults are non-visual filter feeders (Rosen and Hales 1981). During winter, they inhabit mostly deep (> 3 m) and slow or still waters (Pitman 1992a).

Water quality criteria for paddlefish habitat include dissolved oxygen ≥ 5mg/l, pH from 6.5 to 8.2, and chlorides ≤ 170 mg/l. The USGS data cited above show that the Lower Neches has suitable water quality for paddlefish. Only pH values deviated from criteria by falling below the lower limit 37 percent of the time. Paddlefish are more susceptible to poor water quality in earlier life stages according to several studies cited in Pitman (1992b). Concentrations of zinc ≥ 1.75 mg/l or copper ≥ 1.09 mg/l are lethal to paddlefish larvae. A high lipid content may make them susceptible to organic pollutants

which tend to accumulate in fatty tissue. Chlordane and dieldrin have been known to accumulate in yolk sacs to toxic levels. Also, water quality levels that are acceptable for paddlefish could negatively affect paddlefish food sources. Toxaphen suppresses *Daphnia* populations, a common paddlefish food, while cladocerans, a mainstay of paddlefish diet, are susceptible to low pH levels (Pitman 1992).

A TPWD recovery plan is underway with the goal of restoring paddlefish populations to levels that will not only allow the species to be removed from the endangered species list, but also be able to support viable fisheries (Pitman 1992a). To maintain natural recruitment, population density should be one adult per three ha and one juvenile recruit (>658 mm TL) per two ha. On the Neches, this density would require 11,000 adults and 16,500 juvenile recruits. TPWD plans to reach these goals by the year 2001. The recovery plan, directed by Veronica Pitman of TPWD, includes annual stocking of the Trinity, Neches/Angelina, Sabine, Big Cypress Bayou, and Sulphur Rivers. Stocking takes place just above the lowest dam on each river system. On the Neches, the lowest dame is Steinhagen Dam at State Highway 21 (Veronica Pitman, TPWD, personal communication). The plan does not include attempts to establish spawning beds in the Lower Neches or in Village Creek, the only tributary of the Neches with appropriate gravel beds. Fish spawned above Steinhagen Reservoir will presumably make it downstream eventually.

Until recently, the use of gill, hoop, and trammel nets, which often snare paddlefish, was legal in the Lower Neches River between FM 1013 and Interstate 10. In response to recommendations by members of the paddlefish recovery project and others, TPWD no longer grants sport or commercial licenses permitting the use of these nets. However, individuals with previously held commercial licenses who are included in a grandfather clause of the statewide hunting and fishing proclamation are allowed to continue using these nets (State of Texas 1994b).

Another potential problem for paddlefish recovery is the reduction of their range. Paddlefish have very high mobility; mark and recapture data showed that one fish moved 2000 km in less than 8 months (Hubert *et al.* 1984). Their range is gradually being reduced by destruction of spawning areas, restriction of movement by dams, channelization and elimination of backwater areas, reduction of stream flow, and pollution (Hubert *et al.* 1984).

Because dams greatly reduce their movement, the construction of salt water barriers may also present a problem for paddlefish recovery. As a result of a recent permit request to the Corps of Engineers for the construction of two such barriers on the Lower Neches and Pine Island Bayou (see above), TPWD and the Lower Neches River

Valley Authority are conducting a three year study of the effect of salt water barriers on paddlefish (U.S. Dept. of the Army, Corps of Engineers 1994). However, individual fish, mostly from recent stocking efforts by TPWD, are still too small to show up in appreciable numbers in fish census data. When they reach a more easily sampled size, TPWD personnel will be better able to study the effects of salt water barriers on their populations (Veronica Pitman, personal communication).

Case Study: Largemouth Bass

The largemouth bass is an example of a freshwater fish species that could be negatively affected by chemical or physical alteration of BTNP waterways. Because the habitat requirements for this species change as they mature, they require the diversity of freshwater habitat currently found in BTNP. Therefore, largemouth bass could be a potential indicator species for freshwater habitat condition.

As fry, they eat small insects, microcrustaceans, and small fish, while adults prey on larger fish and crawfish. Juveniles also require water speed and turbidity substantially lower than adult fish. For adults, large, slow rivers or streams with many pools are optimal habitat. Adults also prefer soft bottoms with some aquatic vegetation and relatively clear water. Optimal vegetation cover is between 40 and 60 percent; too much vegetation appears to decrease prey visibility. For spawning, largemouth bass prefer a gravel substrate, but will nest on vegetation, roots, sand, mud, or cobble as well (Stuber *et al.* 1982).

Optimum water conditions for the largemouth bass are slightly different than those listed by Hall and Lambou (1990). The dissolved oxygen content needs to be at least 8 mg/l, which is higher than most bottomland hardwood species require. Other requirements are more typical: pH between 6.5 and 8.5, turbidity between 5 and 25 ppm, and optimum temperature between 24 and 30°C (Stuber *et al.* 1982). These fish could be impacted by conversion of nearby forest to rice or soybean cultivation because water runoff from agricultural fields is warmer and consequently lowers the oxygen retention potential (Hall and Lambou 1990).

INVERTEBRATES

The invertebrates are a large and varied group of organisms spanning several phyla. For field studies, they are typically subdivided into two groups, the microinvertebrates and the macroinvertebrates. Microinvertebrates include protozoans and zooplankton, which are known to be locally important in the functioning of stream communities (Smock and Gilinsky 1992). Macroinvertebrates that are known to live in bottomland hardwood habitat include a vast array of arthropods, crustaceans, mollusks, worms, spiders, snails, and butterflies. Macroinvertebrates have long been used to assess water quality and the overall health of aquatic systems. Because of their importance to fish populations and their use as water quality indicators, this report concentrates on aquatic invertebrates.

Aquatic invertebrate populations and water quality have been surveyed for all of the water corridor units of BTNP (Ashcraft 1973, Howard 1973, Darville 1978, and Bass 1979). In 1984-85, Harrel and Hall (1991) conducted a resurvey of the Neches River following pollution abatement and found several species that were not found during the original studies cited above. A survey of insects was conducted in 1982 in the Turkey Creek Unit by Harcombe and Hughes. The results of these surveys are compiled in the invertebrate species list (Table 14).

Microinvertebrates

Free-swimming protozoans are major consumers of bacteria in many stream systems (Carlough and Meyer 1989, Carlough and Meyer 1990). This consumption of bacteria can be very important to the trophic dynamics of the stream by controlling bacterial production and supporting microfilter feeding macroinvertebrates (Smock and Gilinsky 1992). Carlough and Meyer (1989) found net protozoan production in the Ogeechee River in Georgia, a typical blackwater system, to be 600 $\mu g\ C\ l^{-1}\ day^{-1}$.

In most stream types, the zooplankton are also an important component of the food web. Zooplankton consist mainly of species from the Phylum Rotifera and Subphylum Crustacea (Herlong and Mallin 1985). Species lists and density measurements of zooplankton have been compiled for several southern rivers (Smock and Gilinsky 1992). Herlong and Mallin (1985) found Black Creek in South Carolina, a typical blackwater system, to have 48-2093 individuals of microinvertebrates per cubic meter.

Valley Authority are conducting a three year study of the effect of salt water barriers on paddlefish (U.S. Dept. of the Army, Corps of Engineers 1994). However, individual fish, mostly from recent stocking efforts by TPWD, are still too small to show up in appreciable numbers in fish census data. When they reach a more easily sampled size, TPWD personnel will be better able to study the effects of salt water barriers on their populations (Veronica Pitman, personal communication).

Case Study: Largemouth Bass

The largemouth bass is an example of a freshwater fish species that could be negatively affected by chemical or physical alteration of BTNP waterways. Because the habitat requirements for this species change as they mature, they require the diversity of freshwater habitat currently found in BTNP. Therefore, largemouth bass could be a potential indicator species for freshwater habitat condition.

As fry, they eat small insects, microcrustaceans, and small fish, while adults prey on larger fish and crawfish. Juveniles also require water speed and turbidity substantially lower than adult fish. For adults, large, slow rivers or streams with many pools are optimal habitat. Adults also prefer soft bottoms with some aquatic vegetation and relatively clear water. Optimal vegetation cover is between 40 and 60 percent; too much vegetation appears to decrease prey visibility. For spawning, largemouth bass prefer a gravel substrate, but will nest on vegetation, roots, sand, mud, or cobble as well (Stuber *et al.* 1982).

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Macroinvertebrates

Macroinvertebrates are an important component of bottomland hardwood forests and blackwater streams. Like the protozoa, they are major consumers of bacteria (Edwards and Meyer 1987b). Macroinvertebrates in turn are an important food source for all other groups of animals in the ecosystem, especially fish (Benke *et al.* 1979), but also reptiles (Delany *et al.* 1986, Valentine *et al.* 1972), amphibians, and, to a lesser extent, birds and mammals. Benthic species are an important subset of macroinvertebrates that live in or on submerged surfaces. These species are a critical link in the food chain of fish.

Macroinvertebrates are commonly classified according to their method of feeding. The most prevalent feeding guild for a coastal plain river was collector-gatherer (Benke *et al.* 1984); the less important filter feeders and predators were of approximately equal abundance (Table 3).

Table 3: Feeding Guilds in the Satilla River, Georgia (from Benke *et al.* 1984).

	Upper Site			Lower Site		
Functional Group	**Abundance**	**Biomass**	**Production**	**Abundance**	**Biomass**	**Production**
Filtering Collectors	3.7	35.4	11.5	5.0	46.3	11.8
Gathering Collectors	92.7	31.7	71.8	89.6	33.1	70.4
Predators	3.6	32.8	16.6	5.3	20.7	17.7

Note: Values are the percentage contribution to each category by each functional group.

Populations of macroinvertebrates are generally controlled by the hydrology and morphology of the stream, such as size (Smock and Gilinsky 1992). Unstable sediments and frequent changes in the amount of water flow can drastically limit the numbers of macroinvertebrates in the stream. Batema *et al.* (1985) found that invertebrate populations in BLHF respond rapidly to periods of flooding. Parsons and Wharton (1978) found this flood response was the result of both water and nutrient inputs. Stream size also affects invertebrate populations . Felley (1992), in his report on medium-low gradient streams of the Gulf Coastal Plain, summarized the relative abundance of benthic invertebrates in many different stream sizes from several studies (Table 4).

Table 4: Relative Abundance of Benthic Invertebrate Taxa in Different Stream Sizes (from Felley 1992).

Taxon	Feeding Group	Stream Size Large	Medium	Small
Oligochaeta	Substrate, debris feeding	+++	+++	+++
Isopoda	Scavenger, debris feeding	++	+	
Amphipoda	Omnivorous	++	+	
Hydracarina	Piercer	+	+	
Ephemeroptera	Collector-gatherer, scraper	++	++	++
Anisoptera	Engulfer	+	+	
Megaloptera	Engulfer	+	+	
Trichoptera	Shredder, collector-gatherer	+	++	++
Coleoptera	Collector-gatherer, scraper	+	+	++
Chaoborinae	Piercer	++		
Chironomidae	Collector-gatherer, piercer	+++	+++	+++
Ceratopogonidae	Engulfer	++	++	++
Gastropoda	Scraper	++	++	++
Pelecypoda	Filterer	++	++	

Note: +++, abundant; ++, common; +, occasional.

The presence of different types of habitat within a stream system can also affect the abundance and diversity of aquatic invertebrates. There are three main habitats: submerged wooden substrates (snags), sandy benthic habitat of the main channel, and muddy benthic habitat of the backwaters (Benke *et al.* 1984). Abundance and type of rooted aquatic plants (macrophytes) can also strongly affect abundance and species composition of the macroinvertebrates. The living macrophytes stabilize the sediment bed, while macrophyte detritus provides an important source of food for macroinvertebrates. High levels of organic matter due to high litter input or high macrophyte production also provides food and allows greater production. Felley (1992) summarized the relative abundances of different invertebrate taxa for different habitat types (Table 5).

Table 5: Relative Abundance of Benthic Invertebrate Taxa in Different Stream Bottom Types (from Felley 1992).

Taxon	Feeding Group	Sand	Sand and Litter	Mud and Litter	Vegetation
Oligochaeta	Substrate, debris feeding	++	+++	+++	++
Isopoda	Scavenger, debris feeding		+	++	+++
Amphipoda	Omnivorous		+	++	++
Hydracarina	Piercer		+	++	+
Ephemeroptera	Collector-gatherer, scraper	++	++	++	+++
Anisoptera	Engulfer	+	+	+	+
Megaloptera	Engulfer	+	+	+	
Trichoptera	Shredder, collector-gatherer	+	+	++	++
Coleoptera	Collector-gatherer, scraper	+	+	++	+
Chaoborinae	Piercer			++	
Chironomidae	Collector-gatherer, piercer	+++	+++	+++	+++
Ceratopogonidae	Engulfer	++	++	++	++
Gastropoda	Scraper	+	++	++	++
Pelecypoda	Filterer	++	++	++	++

Note: +++, abundant; ++, common; +, occasional.

Snags also provide important macroinvertebrate habitat (Smock *et al.* 1985, Benke *et al.* 1979). In an extensive study of the effects of channel modification on macroinvertebrate production in several blackwater streams, Benke *et al.* (1979) found that the greatest diversity of species and standing stock biomass occurred on snag habitats. The largest groups were filter feeding insects, including caddis flies, black flies, and midges. Benke *et al.* (1984) also showed that snags are also able to support a more diverse group of macroinvertebrates than a sand or mud bottom alone (Table 6).

Table 6: Number of insect and oligochaete genera commonly found in snag, sandy benthic, and muddy benthic habitats (adapted from Benke *et al.* 1984).

	Number of genera		
Order	Mud	Sand	Snags
Diptera	11	15	17
Ephemeroptera	0	0	5
Plecoptera	0	0	2
Trichoptera	3	0	9
Coleoptera	1	1	3
Megaloptera	0	0	1
Odonata	0	1	3

Oligochaeta	2	3	0

In a study of macroinvertebrate populations in several different habitat types in a South Carolina blackwater stream, Smock *et al.* (1985) found that snags and leaf litter were very important to production in these streams, due to the importance of leaf litter as substrate and food. Benke *et al.* (1985) showed that snags are more productive habitats for macroinvertebrates than mud or sand substrates (Table 7).

Table 7: Invertebrate production per m^2 of surface area in a blackwater stream (adapted from Benke *et al.* 1985).

Habitat Type	Mean Annual Biomass (g dry wt m^{-2})	Mean Annual Production (g dry wt m^{-2})
Mud	0.6	13.9
Sand	0.1	13.7
Snag	5.8	57.4

In turn, these macroinvertebrates provide food for larger animals. Benke *et al.* (1985) found that the downstream drift of invertebrates from snags provides an important source of food for fish. Benke *et al.* (1979) also analyzed fish stomach contents. The authors concluded: "The present study strongly confirms evidence from earlier studies that solid substrates are extremely important to the natural functioning of many river ecosystems, and are a major source of food for the fish community."

Harrel and others have conducted a number of surveys of the macroinvertebrate communities of the BTNP water corridors. Studies of Beech Creek, Little Pine Island Bayou, Menard Creek, Turkey Creek, and Big Sandy Creek found that the dominant groups were generally Oligochaeta, with Gastropoda, Chironomidae, Amphipoda, and Diptera locally dominant (Kost 1977, Harrel *et al.* 1978, Harrel *et al.* 1979, Harrel *et al.* 1980, and Harrel *et al.* 1981). These surveys are summarized in Table 8.

Table 8: Dominant benthic macroinvertebrate taxa found in the creeks of BTNP, by percentage of individuals found with number of species in parenthesis (Kost 1977, Harrel *et al.* 1978, Harrel *et al.* 1979, Harrel *et al.* 1980, and Harrel *et al.* 1981).

Group	Beech Creek	Big Sandy Creek	Little Pine Island Bayou	Menard Creek	Turkey Creek
Amphipoda			4% (3)		
Chironomidae	D		22% (23)	45% (38)	
Diptera		22%			
Gastropoda			4% (4)		
Oligochaeta	D	8%	62% (31)	32% (13)	D
Sphaerium	D				
Total Individuals	NA	4076	15263	7462	NA
Total Taxa	**NA**	**171**	**123**	**125**	**134**

Note: D=Dominant, NA=Not Available.

In many blackwater streams, the macroinvertebrates consist almost entirely of insects, since few species of Mollusca can tolerate the acidic conditions (Smock and Gilinsky 1992). When mollusks are present, they are generally *Sphaeriidae*, the fingernail clams, which can withstand lower pH than other mollusks. However, in their study of the fish of BTNP, Suttkus and Clemmer (1979) reported a dense population of the clam *Rangia* along the Neches River just above the mouth of Pine Island Bayou. Their finding suggests that the salt water barrier was far enough upstream to support clams in this area. This conclusion is supported by a study by Harrel (1993) that found that *Rangia* was limited in its range in the Neches River by the frequency of saltwater intrusion.

Water Quality

Water quality plays an important role in determining invertebrate populations. Darville (1978) compared the results of several studies in BTNP creeks and rivers and concluded that polluted waters contained fewer and different taxa than clean waters. The water quality in these studies was affected by sewage discharge, oil field brines, and industrial waste. Contamination was determined by the presence of chlorinated waste, turbidity, and conductivity. Studies on the Neches River also indicated that both pollution and saltwater intrusion can affect invertebrate populations. Harrel *et al.* (1976)

found that the macrobenthic communities in the lower reaches of the Neches River, where saltwater intrusion occurs, have lower diversity when industrial effluents are brought upstream, along with saltwater, from their sources on the lower reaches of the river.

Benthic communities in the Neches River also had higher density and diversity above saltwater barriers than below (Harrel 1975, Harrel *et al.* 1976). This increase in density and diversity is apparently caused by differences in water quality across the barrier. Lower turbidity, sulfates, and salinity and much higher dissolved oxygen content and pH were found on the upstream side of the barriers. The construction of salt water barriers and their impact on stable and flooding conditions could alter invertebrate populations. Other animals that depend on the invertebrates for food, especially fish, would also be affected by such a change in water quality.

Another study was conducted in 1984-85 by Harrel and Hall (1991) to examine any changes in the community structure of the macrobenthos since the original studies on the Neches River in 1971-72. Both numbers of taxa and densities increased at all stations that Harrel and Hall measured (Table 9). Between 1972 and 1985, pollution abatement resulted in a 96 percent reduction in the permitted BOD waste load and decreased presence of other contributing wastes like heavy metals. The stream channel was also deepened to allow navigation of larger watercraft; this dredging removed contaminated sludge from the river bottom. The pollution abatement and dredging, along with increased river discharge, resulted in an effect similar to that of the saltwater barriers: dissolved oxygen concentrations increased and salinity decreased.

Table 9: Annual and extreme number of macrobenthos taxa collected on the Neches River in 1971-72 and 1984-85, by station (Harrel and Hall 1991).

	1971-72		1984-85	
Station	Annual	Extremes	Annual	Extremes
1	9	1-6	22	7-14
2	16	3-10	30	13-21
3	10	0-5	43	15-28
4	10	1-8	25	10-17
5	24	3-13	45	9-29
6	26	7-15	55	18-35
7	26	6-16	55	23-30

Community structure of the macroinvertebrates was also found to be richer in the resurvey. However, because of the long break between studies, a direct relationship between the change in water quality and the change in community structure of the macroinvertebrates cannot be certain.

Management Considerations

Recent studies have shown that timber management practices can affect stream invertebrate populations. For example, Ormerod *et al.* (1993) studied the effect of riparian "buffer strips" on macroinvertebrate communities in upland streams under varying management plans in Wales and Scotland. They found that riparian strips of pure pine plantation had different species composition and abundance than those with broadleaf trees or moorland and grassland vegetation. They recommended the planting of these broadleaf and grassland plants as buffer strips between streams and pine plantations. Though the impact of timber practices on coastal plain streams has not been studied, composition of the vegetation buffering the water corridors of BTNP could have a similar effect on species abundance and composition.

Forest cutting can have a strong negative effect on macroinvertebrate populations of water corridors as well. Decreased shade cover from deforestation of the stream banks can increase the temperature of the rivers. Since many species are sensitive to temperature, such a temperature increase could alter the macroinvertebrate community structure. Logging-induced sediment and debris runoff into streams could also reduce macroinvertebrate populations.

As discussed above, alterations in flooding patterns or stream flow volume could also negatively affect invertebrate populations. Management activities that are likely to affect stream morphology or hydrology need to consider possible impacts on invertebrate populations. Hydrologic alteration could affect fish, bird, or mammal populations as well, due to the importance of invertebrate populations as a food source to the higher trophic levels.

REPORT SUMMARY

This report was designed to advance regional biological diversity protection by collecting current knowledge of the biological resources of the water corridors of BTNP and bottomland hardwood forests in general. This information can now serve as a reference for water corridor management or for further assessment of the resources of BTNP. In order to serve as a reference to water corridor managers, this report includes the following types of information on the corridor units of the BTNP:

1) an inventory of biological survey data of major faunal groups to determine species presence, actual or expected, in the BTNP corridor units and in southeastern bottomland hardwood forests in general;
2) a summary of habitat requirements of these faunal groups in the context of water corridors;
3) discussions of management issues associated with the protection of each faunal group;
4) specific discussions of rare and endangered species in each group;
5) and evidence that certain species or faunal groups may use or depend on certain characteristics of the water corridor units of the BTNP.

Case studies are presented utilizing existing information from BTNP whenever possible. However, since very few ecological studies have been conducted within the corridor units in question, much of the information was derived from studies of other bottomland hardwood forests in the southeastern United States and from more general studies of riparian ecology.

While the information collected above provides a base for management of the water corridors, further review of corridor function is necessary. To achieve meaningful, sustainable goals of conservation of biological diversity in BTNP, knowledge of how the BTNP corridor units fit into an overall landscape level view of regional biological diversity is needed (see Gosselink *et al.* 1990 for an example of this approach). The corridor units within BTNP may protect regional biological diversity through three primary roles:

1) preserves for bottomland hardwood forest species,
2) population dispersal conduits within the landscape,
3) and buffers for the protection of the aquatic community.

We have defined the corridor as consisting of two distinct biological communities: the bottomland hardwood forest community located on the flood plain terrace adjacent to the waterway and the aquatic community present within the waterway. While the

communities are fairly distinct, an ecotone exists between these two communities, as well as between the BLHF and the adjacent uplands. Understanding the biotic exchange between these three communities is also important. Based on an evaluation of the relevant ecological literature, the following discussions define each of these potential roles of the water corridors and summarize the kind of landscape level information needed to comprehensively evaluate the effectiveness of the corridors in preserving biological diversity in BTNP.

Water Corridor Units as Bottomland Hardwood Forest (BLHF) Preserves

The importance of a corridor unit as a preserve for BLHF is determined by the degree to which that unit represents and will continue to represent a functioning bottomland forest community such as would originally have been present at that location prior to the massive land use changes associated with European colonization. In this report, many of the characteristics of a functioning BLHF were mentioned:

1) mature forest canopy of predominantly mast-producing species;
2) abundance of buttrot, bole, and branch cavities;
3) periodic flooding with the deposition of rich alluvial soils;
4) large tracts, at least 30 ha in size, in order to maintain viable populations of BLHF interior species (Harris 1988a);
5) natural transition zones between BLHF and adjacent uplands;
6) and a large enough area to sustain the dynamics of natural disturbance processes such as windthrow and insect infestations.

As the above ecological characteristics are diminished by human activity, the integrity of the BLHF declines. The point at which a sustainable BLHF community is lost is unclear. Certainly on a regional level, irreversible changes in BLHF have already occurred, such as the extinction or near-extinction of the ivory-billed woodpecker, red wolf, Louisiana black bear, Swainson's warbler, and others (Burdick *et al.* 1989). The degree to which the loss of BLHF species will continue locally within the corridor units of BTNP is largely dependent on the pattern of fragmentation associated with land use practices within and adjacent to the corridor unit, as well as on the alteration of hydrological patterns through flood control. Below is a brief review of the effects of habitat fragmentation. The ecological impact of flood control activity on the BLHF is addressed in a separate report (Hall 1993).

Fragmentation

The ecological impact of fragmentation caused by pipelines, highways, agriculture, timber harvests, and residential developments can vary significantly. In general, however, habitat fragmentation has two major interrelated consequences for biological diversity: population isolation and a decrease in effective population size; and creation of edge habitat and "edge" effects. The degree of population isolation and the extent of any edge effects will be related to the size and shape of the fragmented forest area. While the effects of fragmentation on the ecology of BLHF have been virtually unstudied (Harris 1988a), some of the likely consequences can be delineated.

Population Isolation

As a community is fragmented into smaller and smaller pieces, species that are not able to move between fragments become isolated. Each population will be smaller and thus at greater risk of local extinction due to random mortality events or the deleterious effects of inbreeding (Soulé 1987). Landscape level disturbances that may have been compartmentalized in an unfragmented landscape and are important to the maintenance of landscape-level biological diversity, such as fire, flooding, hurricane damage, and insect outbreaks, may not occur at all, or may have catastrophic effects, within the smaller fragments. Dramatic alteration of predator-prey and plant-herbivore interactions by fragmentation of the landscape into isolated patches can also contribute to local extinction.

The degree to which a population is affected by fragmentation depends on the species in question and the way in which the community is fragmented. For example, certain interior bird species will not cross highway rights-of way (Wilcove *et al.* 1986). Timber practices can create a mosaic of successional forest, trapping some amphibian populations in isolated mature forest stands, despite a continuous canopy cover (Rudolph and Dickson 1990).

Edge Effects

Whenever there is an abrupt discontinuity in the spatial cover of a community, an edge is produced. River corridors are bisected by a natural edge, one that is associated with the waterway opening. Human-caused edges, such as those associated with agricultural fields, powerlines, and roads, often result in rapid and sometimes irreversible change in community structure (Harris 1988b). The microclimatic conditions at an edge are very different from that of the interior. Temperature, light penetration, and exposure

to wind generally increase in edges (Lovejoy *et al.* 1986). These environmental changes promote an increase in tree mortality and an increased abundance of early successional species.

Change in forest structure at the edge depresses interior bird populations near the margins (Wilcove *et al.* 1986). As described earlier in the section on birds, nest parasitic birds such as cowbirds flourish in edge habitat, further depressing interior bird populations (Brittingham and Temple 1983). Edge effects resulting from habitat fragmentation and the subsequent rise in nest parasitism probably caused the demise of the Bachman's warbler as an interior species in southeastern BLHF (Harris 1988a).

This negative influence or edge effect has been quantified in several communities and has been shown to extend beyond 100 m into the forest, with subtle species compositional effects extending up to 1 km (Wilcove 1985, Lovejoy *et al.* 1986, and Harris 1988a). Edges also facilitate the invasion of exotic species which may function as predators, such as domestic cats and dogs, or potential competitors, such as Chinese tallow, in an interior community. Also, through increased road kills or increased predation in open areas, mortality in species that attempt to migrate across edges can increase (Harris and Gallagher 1989). Increased edge also facilitates human access to the interior resulting in increased hunting, trampling, or illegal logging. Since the edge-to-interior ratio for the river corridor units of BTNP is extremely high, evaluating the extent of edge effects in the water corridors is essential to evaluating the corridors effectiveness as BTHF preserves.

Water Corridor Units as Population Dispersal Conduits within the Landscape

The concept that corridors will function as dispersal conduits between larger units within a fragmented preserve was originally based on the equilibrium theory of island biogeography (MacArthur and Wilson 1974). This theory states that the number of species present on an island, or in an isolated preserve, is determined by the balance between the rate of colonization by new species and rate of extinction of resident species. Since corridors potentially increase the rate of colonization relative to extinction, corridors could therefore increase the number of species present in a given preserve, making them a viable conservation tool for the design of nature preserves (Wilson and Willis 1975). The equilibrium theory of island biogeography underwent a period of heavy criticism in the 1980's (for a review, see Simberloff *et al.* 1992) and was deemed inapplicable to most insular communities since changes in local extinction rate, or population turnover, were rarely demonstrated. Despite the lack of an empirical basis

and subsequent lack of acceptance in the scientific community, the theory of island biogeography has been widely embraced by the conservation community as a basis for nature preserve design, especially for the use of corridors within specific designs (Simberloff and Cox 1987).

Recently, the metapopulation concept has replaced island biogeography theory as a key to our understanding of the dynamics of habitat islands (Merriam 1991). A metapopulation is an interconnected set of subpopulations that exist in a matrix of otherwise inhospitable habitats (Heinein and Merriam 1990). As habitat fragmentation increases, population isolation can lead to a greater risk of local extinctions of subpopulations and a breakdown of the metapopulation structure. Corridors have been proposed as a mechanism to facilitate movement between these isolated subpopulations, allowing for the reestablishment of the metapopulation (Noss 1987). Much of the recent research has been based on simulation modeling and field manipulations of mice populations in simple landscapes (Merriam and Lanoue 1990, Merriam 1991). Very little empirical data on the actual use of corridors by specific species exists and most reported observations have been found to be ambiguous (Simberloff and Cox 1987, Ezzell 1992, and Simberloff *et al.* 1992). However, the limited data available concur on one specific point: effective corridors must contain habitat of suitable quality for the species of interest (Henein and Merriam 1990 and Harrison 1992).

To assess the extent that the corridor units of BTNP function in this dispersal capacity, several questions must be considered:

1) Which species that are present in the larger units use the corridors?
2) Would the species disperse without the corridors?
3) If a species uses the corridors, how does dispersal affect the population size and genetics of the metapopulation?
4) What aspects of corridor size, shape, and structure promote dispersal?
5) What human land uses or other factors degrade corridor integrity?

While dispersal corridors have potential benefits to the preservation of biological diversity in a natural area such as BTNP, several costs should also be considered:

1) Does corridor presence promote the spread of introduced species and pathogens?
2) Does corridor presence change the patterns of predation and competition within larger units?
3) Given current landscape configurations, does corridor presence over-promote the abundance of certain mobile species, such as white-tailed deer, within the larger units?
4) Do corridors result in increased dispersal out of NPS lands resulting in increased rates of mortality for some species?

Water Corridor Units as a Buffer for the Protection of the Aquatic Community

Since water quality is a key determinant of aquatic community integrity, corridors serve a potentially valuable role in the protection of aquatic diversity (Décamps 1993). Empirically, forest strips along waterways have been shown to buffer waterways from the negative effects of adjacent land use practices on water quality such as siltation from erosion and pesticide, fertilizer, and herbicide run-off (Naiman *et al.* 1993). In a study of a floodplain forest in Arkansas, riparian forest buffers resulted in a 50 percent reduction in sediment loading in the river as well as a 50 percent reduction in phosphate runoff and an 80 percent reduction in nitrate loading (Anderson and Masters 1991). Forested corridors also serve to shade the river bank, creating variation in the thermal regime of the river upon which certain aquatic species depend. Forested strips are a source of snags, an important element of habitat diversity within the aquatic system and a productive substrate for invertebrates.

The need for streamside buffers also depends on the type and intensity of adjacent land uses. In East Texas, one of the major sources of non-point pollution and erosion is the harvest of local timber. The Texas Forestry Association (TFA) has advocated the creation of Streamside Maintenance Zones, defined as the "area on each side of the banks and above the head of intermittent streams, perennial streams, and other drains or bodies of water where precaution in carrying out forest practices is needed to protect bank edges and water quality" (TFA 1989). Within the area of the SMZ, human activity is limited and the forest floor is to remain relatively undisturbed. However, studies have shown that limited harvesting within the SMZ may actually benefit water quality. Periodic tree harvests can cause a net uptake and removal of nutrients from the stream bank, thereby

counterbalancing stream inputs from upland agricultural or silvicultural activities (Lowrance *et al.* 1984).

Several aspects of a particular riparian area, such as the type of adjacent land use and the response of the aquatic community to changes in water quality, affect the need for and the function of streamside buffers. Determining whether the corridor units of BTNP buffer aquatic communities from the impact of adjacent land uses requires consideration of these factors:

1) How does aquatic diversity respond to increased width of the forest strip?
2) What are the primary deleterious products of different land use practices that affect water quality and species diversity?
3) What components of community structure and function within a bottomland hardwood forest enhance this buffering capacity?
4) In these corridors, is quality of water as it enters the corridor more important than characteristics of the buffer zone within the corridor?

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APPENDICES

Appendix A: Species found in bottomland hardwood forest (BLHF), including type of use of BLHF, presence in Big Thicket (BITH), and threatened or endangered status, divided into faunal groups.

Appendix A.1: Bird species of BLHF and BITH.

Order / Family	Scientific name[3]	Common name[4]	BLHF stat.[5]	BITH pres.[6]	T&E stat.[7]
Gaviiformes					
Gaviidae		**Loons**			
	Gaiva immer	common loon	V	yes	
Podicipediformes					
Podicipedidae		**Grebes**			
	Podiceps nigricollis	eared grebe	F	yes	
	Podilymbus podiceps	pied-billed grebe	F	yes	
Pelecaniformes					
Pelecanidae		**Pelicans**			
	Pelecanus erythrorhynchos	American white pelican	V	yes	

[3] Family, genus, and species names were determined from Check-list of North American Birds, 6th Edition as prepared by the American Ornitologists' Union (1983).

[4] Common names were determined from the Check-list of North American Birds, 6th Edition as prepared by the American Ornitologists' Union (1983).

[5] Type of use of bottomland hardwood forest was determined from BTNP surveys and general literature on BLHF including Patrick *et al.* (1981), Wharton *et al.* (1982), Frentress (1986), Mitsch and Gosselink (1986), Bellrose and Trudeau (1988), Niering (1988), Burdick *et al.* (1989), and Ernst and Brown (1989). Status codes are:
O = Obligate inhabitant of bottomland hardwood forest
F = Facultative inhabitant of bottomland hardwood forest
V = Occasional visitor to bottomland hardwood forest

[6] BTNP presence was determined from BTNP surveys and general literature including Fisher (1974), Bryan *et al.* (1976), Biercevicz (1977), Deuel & Fisher (1977), Ramsey (1980), Williams (1981), and McGuffin (1984).

[7] Federal endangered status was taken from USF&WS Report to Congress: Endangered and Threatened Species Recovery Program. Texas endangered status taken from TP&WD Endangered Resources Annual Status Report.
E = Endangered T = Threatened
C2, etc. refers to Federal status. These species are being considered for listing.

Appendix A.1: Bird species of BLHF and BTNP (continued).

Order / Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
Phalacrocoracidae		**Cormorants**			
	Phalacrocorax auritus	double-crested cormorant	F	yes	
	Phalacrocorax olivaceus	olivaceus cormorant	F	yes	
Anhingidae		**Darters**			
	Anhinga anhinga	anhinga	F	yes	
Fregatidae		**Frigate-birds**			
	Fregata magnificens	magnificent frigatebird	F	yes	
Ciconiiformes					
Ardeidae		**Herons and Bitterns**			
	Ardea herodias	great blue heron	F	yes	
	Botaurus lentiginosus	American bittern	F		
	Bubulcus ibis	cattle egret	V	yes	
	Butorides striatus	green-backed Heron	F	yes	
	Casmerodius albus	great egret	F	yes	
	Egretta caerulea	little blue heron	F	yes	
	Egretta rufescens	reddish egret	V		
	Egretta thula	snowy egret	F	yes	
	Egretta tricolor	tricolored heron	F	yes	
	Ixobrychus exilis	least bittern	F		
	Nycticorax nycticorax	black-crowned night-heron	F	yes	
	Nycticorax violacea	yellow-crowned night-heron	O	yes	
Threskiornithidae		**Ibises and Spoonbills**			
	Ajaia ajaja	roseate spoonbill	V		
	Eudocimus albus	white ibis	V		
	Plegadis chihi	white-faced ibis	F		C2, T
Ciconiidae		**Storks and Wood Ibises**			
	Mycteria americana	wood stork	F	yes	yes
Anseriformes					
Anatidae		**Surface Feeding Ducks**			
	Aix sponsa	wood duck	O	yes	
	Anas acuta	northern pintail	F		
	Anas clypeata	northern shoveler	F	yes	
	Anas cyanoptera	cinnamon teal	F	yes	
	Anas discors	blue-winged teal	F	yes	
	Anas fulvigula	mottled duck	F	yes	
	Anas platyrhynchos	mallard duck	F		
	Anas rubripes	American black duck	F		
	Anas strepera	gadwall	F	yes	
	Anser albifrons	greater white-fronted goose	F		

Appendix A.1: Bird species of BLHF and BTNP (continued).

Order / Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
	Aythya affinis	lesser scaup	V		
	Aythya americana	redhead	V	yes	
	Aythya collaris	ring-necked duck	F	yes	
	Aythya marila	greater scaup	V		
	Aythya valisineria	canvasback	V	yes	
	Branta canadensis	Canada goose	F	yes	
	Chen caerulescens	snow goose	F	yes	
	Dendrocygna bicolor	fulvous whistling duck	F		
	Lophodytes cucullatus	hooded merganser	F		
	Mareca americana	American widgeon	F		
	Melanitta perspicillata	surf scooter	V		
	Mergus serrator	red-breasted merganser	V		
	Oxyura jamaicensis	ruddy duck	F		
Falconiformes					
Cathartidae		**American Vultures**			
	Cathartes aura	turkey vulture	V	yes	
	Coragyps atratus	black vulture	V	yes	
Accipitridae		**Hawks, Kites, Harriers, and Eagles**			
	Accipiter cooperii	Cooper's hawk	F	yes	
	Accipter striatus	sharp-shinned hawk	F	yes	
	Buteo jamaicensis	red-tailed hawk	F	yes	
	Buteo lineatus	red-shouldered hawk	O	yes	
	Buteo platypterus	broad-winged hawk	F	yes	
	Buteo swainsoni	Swainson's hawk	F	yes	
	Circus cyaneus	northern harrier	F	no	
	Elanoides forficatus	American swallow-tailed kite	O		yes
	Haliaeetus leucocephalus	bald eagle	F	no	ET, E
	Ictinia mississippiensis	Mississippi kite	F	yes	
	Pandion haliaetus	osprey	F		
Falconidae		**Caracas and Falcons**			
	Falco columbarius	merlin	F	yes	
	Falco peregrinus	peregrine falcon	V		T, T
	Falco sparverius	American kestrel	V	yes	
	Polyborus cheriway	crested caracara	V		

Appendix A.1: Bird species of BLHF and BTNP (continued).

Order	Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
Galliformes						
	Phasianidae		**Quails, Partridges, and Pheasants**			
		Coinus virginianus	northern bobwhite	V	yes	
		Meleagris gallopavo	wild turkey	F	yes	
		Phasianus colchicus	ring-necked pheaseant	V		
Gruiformes						
	Rallidae		**Rails, Gallinules, and Coots**			
		Fluica americana	American coot	F	yes	
		Gallinula chloropus	common moorhen	F		
		Porphyrula martinica	purple gallinule	F		
		Porzana carolina	sora	F		
		Rallus elegans	king rail	F		
		Rallus limicola	Virginia rail	F		
		Rallus longirostris	clapper rail	V		
	Gruidae		Cranes			
		Grus canadensis	sandhill crane	F	yes	yes
Charadriiformes						
	Charadriidae		**Plovers and Turnstones**			
		Arenaria interpres	ruddy turnstone	V	yes	
		Charadrius semipalmatus	semipalmated plover	V		
		Charadrius vociferus	killdeer	F	yes	
		Pluvialis dominica	lesser goldenplover	V		
		Pluvialis squatarola	black-bellied plover	V		
	Recurvirostridae		Avocets and Stilts			
		Himantopus mexicanus	black-necked stilt	V	yes	
		Recurvirostra americana	american avocet	V	no	
	Scolopacidae		**Woodcocks, Snipes, and Sandpipers**			
		Actitis macularia	spotted sandpiper	F	yes	
		Calidris bairdii	Baird's sandpiper	V	yes	
		Calidris fuscicollis	white-rumped sandpiper	V		
		Calidris mauri	western sandpiper	V		
		Calidris melanotos	pectoral sandpiper	V		
		Calidris pusillus	semipalmated sandpiper	V	yes	
		Capella gallanago	common snipe	F	no	
		Catoptrophorus semipalmatus	willet	V		
		Limnodromus griseus	short-billed dowitcher	V	yes	
		Limnodromus scolopaceus	long-billed dowitcher	V	yes	
		Numenius americanus	long-billed curlew	V		

Appendix A.1: Bird species of BLHF and BTNP (continued).

Order Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
	Numenius borealis	eskimo curlew	V		E, E
	Scolopax minor	American woodcock	O	yes	
	Tringa flavipes	lesser yellowlegs	F	yes	
	Tringa melanoleucus	greater yellowlegs	F	yes	
	Tringa solitaria	solitary sandpiper	O	yes	
	Trygnites subruficollis	buff-breasted sandpiper	V	yes	
Phalaropodidae		**Phalaropes**			
	Steganopus tricolor	Wilson's phalarope	V	yes	
Laridae		Gulls and Terns			
	Chlidonians niger	black tern	V		
	Larus atricilla	laughing gull	V		
	Larus delarensis	ring-billed gull	V		
	Larus philadelphia	Bonaparte's gull	V	yes	
	Sterna caspia	caspian tern	V	yes	
	Sterna forsteri	Foster's tern	F		
	Sterna maxima	royal tern	V		
	Sterna nilotica	gull-billed tern	V		
	Sterna sandvicensis	sandwich tern	V		
	Rynchops niger	black skimmer	V		
Columbiformes					
Columbidae		**Pigeons and Doves**			
	Columba livia	rock dove	V	yes	
	Zenaidura macroura	mourning dove	V	yes	
Cuculiformes					
Cuculidae		**Cuckoos, Roadrunners, and Anis**			
	Coccyzus americanus	yellow-billed cuckoo	F	yes	
	Coccyzus erthyrophalmus	black-billed cuckoo	F	yes	
	Crotophagus sulcirostris	groove-billed ani	F	yes	
	Geococcyx californianus	greater roadrunner	V	yes	
Strigiformes					
Tytonidae		**Barn-Owls**			
	Otus asio	eastern screech owl	F	yes	
	Tyto alba	barn owl	V		

Appendix A.1: Bird species of BLHF and BTNP (continued).

Order Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
Strigidae		**Typical Owls**			
	Aegolius acadicus	northern saw-whet owl	F		
	Asio flammeus	short-eared owl	F		
	Bubo virginianus	great horned owl	F	yes	
	Strix varia	barred owl	F	yes	
Caprimulgiformes					
Caprimulgidae		**Goatsuckers**			
	Chordeiles minor	common nighthawk	V	yes	
	Caprimulgus carolinensis	Chuck-will's-widow	F	yes	
	Caprimulgus vociferus	whip-poor-will	F	yes	
Apodiformes					
Apodidae		**Swifts**			
	Chaetura pelagica	chimney swift	V	yes	
Trochilidae		**Hummingbirds**			
	Archilochus colubris	ruby-throated hummingbird	F	yes	
Coraciiformes					
Alcedinidae		**Kingfishers**			
	Ceryle alcyon	belted kingfisher	F	yes	
Piciformes					
Picidae		**Woodpeckers**			
	Campephilus principalis	ivory-billed woodpecker	O		E, E
	Colaptes auratus	northern flicker	V	yes	
	Dryocopus pileatus	pileated woodpecker	F	yes	
	Melanerpes erythrocephalus	red-headed woodpecker	F	yes	
	Melanorpes carolinus	red-bellied woodpecker	F	yes	
	Picoides borealis	red-cockaded woodpecker	V	yes	E, E
	Picoides pubescens	downy Woodpecker	F	yes	
	Picoides villosus	hairy woodpecker	F	yes	
	Sphyrapicus varius	yellow-bellied sapsucker	F	yes	
Passeriformes					
Tyrannidae		**Flycatchers**			
	Contopus borealis	olive-sided flycatcher	F	yes	
	Contopus virens	eastern wood-pewee	F	yes	
	Empidonax virescens	acadian flycatcher	F	yes	
	Myiarchus crinitus	great crested flycatcher	V	yes	
	Pyrocephalus rubinus	vermillion flycatcher	F	yes	

Appendix A.1: Bird species of BLHF and BTNP (continued).

Order / Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
	Sayornis phoebe	eastern phoebe	F	yes	
	Tyrannus tyrannus	eastern kingbird	V	yes	
	Tyrannus verticalis	western kingbird	V		
	Tyranus forficata	scissor-tailed flycatcher	V	yes	
Alaudidae		**Larks**			
	Eremophila alpestris	horned lark	V		
Hirundinidae		**Swallows**			
	Hirundo pyrrhonota	cliff swallow	V	yes	
	Hirundo rustica	barn swallow	V	yes	
	Progne subis	purple martin	V	yes	
	Riparia riparia	bank swallow	F	yes	
	Stelgidopteryx ruficollis	southern rough-winged swallow	F	yes	
	Tachycineta bicolor	tree swallow	F	yes	
Corvidae		**Jays, Magpies, and Crows**			
	Corvus brachyrhynchos	American crow	F	yes	
	Corvus ossifragus	fish crow	F	yes	
	Cyanocitta cristata	blue Jay	F	yes	
Paridae		**Titmice, Verdins, and Bushtits**			
	Parus bicolor	tufted titmouse	F	yes	
	Parus caroinensis	carolina chickadee	V	yes	
Sittidae		**Nuthatches**			
	Sitta canadensis	red-breasted nuthatch	F	yes	
	Sitta carolinensis	white-breasted nuthatch	F	yes	
	Sitta pusilla	brown-headed nuthatch	V	yes	
Certhidae		**Creepers**			
	Certhia americana	brown creeper	V	yes	
Troglodytidae		**Wrens**			
	Cistothorus platensis	sedge wren	V	yes	
	Thryothorus bewickii	Bewick's wren	F	yes	
	Thryothorus ludovicianus	carolina wren	F	yes	
	Troglodytes troglodytes	winter wren	F	yes	
Muscicapidae		**Muscicapids**			
	Catharus fuscenscens	veery	F	yes	
	Catharus guttatus	hermit thrush	F	yes	
	Catharus minimus	gray-cheeked thrush	F	yes	
	Catharus ustulatus	Swainson's thrush	F	yes	
	Hylocichla mustelina	wood thrush	F	yes	
	Sialia sialis	eastern bluebird	V	yes	
	Turdus migratorius	American robin	F	yes	

Appendix A.1: Bird species of BLHF and BTNP (continued).

Order / Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
	Polioptila caerulea	blue-gray gnatcatcher	F	yes	
	Regulus calendula	ruby-crowned kinglet	F	yes	
	Regulus satrapa	golden-crowned kinglet	F	yes	
Mimidae		**Mockingbirds and Thrashers**			
	Dumetella carolinensis	gray catbird	F	yes	
	Mimus polyglottos	mockingbird	V	yes	
	Toxostoma rufum	brown thrasher	V	yes	
Motacillidae		**Pipits**			
	Anthus spinoletta	water pipit	V		
	Anthus spragueii	Sprague's pipit	V	yes	
Bombycillidae		**Waxwings**			
	Bombycilla cedrorum	cedar waxwing	V	yes	
Laniidae		**Shrikes**			
	Lanius lodovicianus	loggerhead shrike	V	yes	
Sturnidae		**Starlings**			
	Sturnus vulgaris	European starling	V	yes	
Vireonidae		**Vireos**			
	Vireo bellii	Bell's vireo	V	yes	
	Vireo flavifrons	yellow-throated vireo	F	yes	
	Vireo gilvus	warbling vireo	F	yes	
	Vireo griseus	white-eyed vireo	F	yes	
	Vireo olivaceus	red-eyed vireo	F	yes	
	Vireo philadelphicus	Philadelphia vireo	F	yes	
	Vireo solitarius	solitary vireo	F	yes	
Emberizidae		**Emberizids**			
	Dendroica castanea	bay-breasted warbler	V	yes	
	Dendroica cerulea	cerulean warbler	F	yes	
	Dendroica coronata	yellow-rumped warbler	F	yes	
	Dendroica discolor	prairie warbler	V	yes	
	Dendroica dominica	yellow-throated warbler	F	yes	
	Dendroica fusca	Blackburnian warbler	F	yes	
	Dendroica magnolia	magnolia warbler	F	yes	
	Dendroica palmarum	palm warbler	V	yes	
	Dendroica pensylvanica	chestnut-sided warbler	V	yes	
	Dendroica petechia	yellow warbler	F	yes	
	Dendroica pinus	pine warbler	V	yes	
	Dendroica virens	black-throated green warbler	V	yes	
	Geothlypis trichas	common yellowthroat	O	yes	
	Helmitheros vermivorus	worm-eating warbler	F	yes	
	Icteria virens	yellow-breasted chat	V	yes	
	Limnothlypis swainsonii	Swainson's warbler	O	yes	
	Mniotilta varia	black-and-white warbler	F	yes	

Appendix A.1: Bird species of BLHF and BTNP (continued).

Order / Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
	Oporornis forosus	Kentucky warbler	F	yes	
	Oporornis philadelphia	mourning warbler	V	yes	
	Parula americana	northern parula	F	yes	
	Protonotaria citrea	prothonotary warbler	O	yes	
	Seiurus aurocapillus	ovenbird	F	yes	
	Seiurus motacilla	Louisiana waterthrush	F	yes	
	Vermivora bachmanii	Bachman's warbler	O		extinct
	Vermivora celata	orange-crowned warbler	F	yes	
	Vermivora chrysoptera	golden-winged warbler	F	yes	
	Vermivora pinus	blue-winged warbler	V	yes	
	Vermivora ruficapilla	Nashville warbler	V	yes	
	Wilsonia canadensis	Canada warbler	F	yes	
	Wilsonia cirtina	hooded warbler	V	yes	
	Setophaga ruticilla	American redstart	F		
	Piranga ludoviciana	western tananger	V	yes	
	Piranga olivacea	scarlet tananger	V	yes	
	Piranga rubra	summer tananger	F	yes	
	Agalaius phoeniceus	red-winged blackbird	F	yes	
	Euphagus carolinus	rusty blackbird	O	yes	
	Icterus galbula	northern oriole	V	yes	
	Icterus spurius	orchard oriole	V	yes	
	Molothrus ater	brown-headed cowbird	F	yes	
	Quiscalus mexicanus	great tailed grackle	F		
	Quiscalus quiscula	common grackle	F	yes	
	Sturnella magna	eastern meadowlark	V	yes	
	Xanthocephalus xanthcephalus	yellow-headed blackbird	F	yes	
Fringillidae		**Grosbeaks, Finches, Sparrows, and Buntings**			
	Aimophila aestivalis	Bachman's sparrow	F	yes	C2, T
	Ammodramus caudacuta	sharp-tailed sparrow	V	yes	
	Ammodramus henslowii	Henslow's sparrow	V	yes	
	Ammodramus maritimus	seaside sparrow	V		extinct
	Ammodramus savannarum	grasshopper sparrow	V	yes	
	Cardinalis cardinalis	northern cardinal	F	yes	
	Carduelis pinus	pine siskin	V	yes	
	Carduelis tristis	American goldfinch	V	yes	
	Carpodacus purpureus	purple finch	F	yes	
	Coccothraustes vespertinus	evening grosbeak	V	yes	
	Guiraca caerulea	blue grosbeak	F	yes	
	Junco Hyemalis	dark-eyed junco	V	yes	
	Melospiza georgiana	swamp sparrow	F	yes	
	Melospiza lincolnii	Lincoln's sparrow	V	yes	
	Melospiza melodia	song sparrow	F	yes	
	Passerculus sandwichensis	savannah sparrow	V		

Appendix A.1: Bird species of BLHF and BTNP (continued).

Order	Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
		Passerella iliaca	fox sparrow	F	yes	
		Passerherbulus caudacutus	Le Conte's sparrow	V	yes	
		Passerina ciris	painted bunting	F	yes	
		Passerina cyanea	indigo bunting	F	yes	
		Pheucticus ludovicianus	rose-breasted grosbeak	F	yes	
		Pheucticus melanocephalus	black-headed grosbeak	V	yes	
		Pipilo erythrophthalmus	rufous-sided towhee	F	yes	
		Pooecetes gramineus	vesper sparrow	V	yes	
		Spiza americana	dickcissel	V	yes	
		Spizella passerina	chipping sparrow	V	yes	
		Spizella pusilla	field sparrow	V	yes	
		Zonotrichia albicollis	white-throated sparrow	F	yes	
		Zonotrichia leucophrys	white crowned sparrow	V	yes	
		Zonotrichia querula	Harris' sparrow	V	yes	
	Passeridae		**Old World Sparrows**			
		Passer domesticus	house sparrow	V	yes	

Appendix A.2: Mammal species of BLHF and BITH.

Order / Family	Scientific name	Common name	BLHF stat.[8]	BITH pres.[9]	T&E stat.[10]
Artiodactyla					
Cervidae		**Deer**			
	Odocoileus virginianus	white-tailed deer	F	yes	
Suidae		**Old World Swine**			
	Sus scrofa	feral hog	F	yes	
Carnivora					
Canidae		**Dogs, Wolves, and Foxes**			
	Canis domesticus	domestic dog	F	yes	
	Canis latrans	coyote	F	yes	
	Canis rufus	red wolf			extinct
	Urocyon cinereoargenteus	gray fox	F	yes	
	Vulpes vulpes	red fox	F	yes	
Felidae		**Cats**			
	Felis catus	domestic cat	F	yes	
	Felis concolor coryi	cougar	F	yes	yes
	Lynx rufus	bobcat	F	yes	
Mustelidae		**Weasels, Skunks, and Otters**			
	Conepatus mesoleucus temalestes	Big Thicket hog-nosed skunk	F	yes	C2,S1
	Lutra canadensis	river otter	O	yes	
	Mephitis mephitis	striped skunk	F	yes	
	Mustela frenata	long-tail weasel	F	yes	
	Mustela vison	mink	O	yes	
	Spilogale putorius	eastern spotted skunk	F	yes	
	Taxidea taxus	badger	F	yes	

[8] Type of use of bottomland hardwood forest was determined from BTNP surveys (see below) and general literature on BLHF including Patrick *et al.* (1981), Wharton et al. (1982), Schmidly (1983), Frentress (1986), Mitsch and Gosselink (1986), Fritzel (1988), Lea (1988), Niering (1988), and Ernst and Brown (1989).

O = Obligate inhabitant of bottomland hardwood forest.
F = Facultative inhabitant of bottomland hardwood forest.
V = Occasional visitor to bottomland hardwood forest

[9] Presence in BTNP was determined from BTNP surveys and general literature on BITH including Rogers and Schmidly (1978), Schmidly *et al.* (1979), and Halstead (1981).

[10] Federal endangered status was taken from USF&WS Report to Congress: Endangered and Threatened Species Recovery Program. Texas endangered status taken from TP&WD Endangered Resources Annual Status Report.

E = Endangered T = Threatened
C2, etc. refers to federal status. These species are being considered for listing.

Appendix A.2: Mammal species of BLHF and BITH (continued).

Order / Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
Procyonidae		**Raccoons and Coatis**			
	Bassariscus astutus	ringtail	F	yes	
	Procyon lotor	raccoon	F	yes	
Ursidae		**Bears**			
	Ursus americanus	black bear	F		T(S/A),E
Chiroptera					
Molossidae		**Free-tailed Bats**			
	Tadarida brasiliensis	Brazilian free-tailed bat	F	yes	
Vespertilionidae		**Plain-nosed Bats**			
	Eptesicus fuscus	big brown bat	F	yes	
	Lasionycteris noctivagans	silver-haired bat	F	yes	
	Lasiurus borealis	red bat	F	yes	
	Lasiurus cinereus	hoary bat	F	yes	
	Lasiurus intermedius	northern yellow bat	F	yes	
	Lasiurus seminolus	seminole bat	F	yes	
	Myotis austroriparius	southeastern bat	O	yes	C2, T
	Nycticeius humeralis	evening bat	F	yes	
	Pipistrellus subflavus	eastern pipistrelle	F	yes	
	Plecotus rafinesquii	Rafinesque's Big-eared bat	F	yes	C2, T
Edentata					
Dasypodidae		**Armadillos**			
	Dasypus novemcinctus	nine-banded armadillo	F	yes	
Insectivora					
Soricidae		**Shrews**			
	Blarina carolinensis	southern short-tailed shrew	F	yes	
	Cryptotis parva	least shrew	F	yes	
Talpidae		**Moles**			
	Scalopus aquaticus	eastern mole	F	yes	
Lagomorpha					
Leporidae		**Hares and Rabbits**			
	Lepus californicus	black-tailed jack rabbit	F	yes	
	Sylvilagus aquaticus	swamp rabbit	O	yes	
	Sylvilagus floridanus	eastern cottontail	F	yes	
Marsupialia					
Didephidae		**Opossums**			
	Didelphis virginiana	Virginia opossum	F	yes	

Appendix A.2: Mammal species of BLHF and BITH (continued).

Order Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
Rodentia					
Capromyodae		**Nutria**			
	Myocastor coypus	nutria	O	yes	
Castoridae		**Beavers**			
	Castor canadensis	beaver	O	yes	
Cricetidae		**Mice, Rats, Lemmings, and Voles**			
	Baiomys taylori	northern pygmy mouse	F	yes	
	Microtus pinetorum	pine vole	F	yes	
	Neotoma floridana floridana	eastern woodrat	F	yes	yes
	Ochrotomys nuttalli	golden mouse	F	yes	
	Ondatra zibethicus	muskrat	O	yes	
	Oryzomys palustris	march rice rat	F	yes	
	Peromyscus gossypinus	cotton mouse	F	yes	
	Peromyscus leucopus	white-footed mouse	F	yes	
	Peromyscus maniculatus	deer mouse	F	yes	
	Reithrodontomys fulvescens	fulvous harvest mouse	F	yes	
	Reithrodontomys humulis	eastern harvest mouse	F	yes	
	Reithrodontomys montanus	plains harvest mouse	F	yes	
	Sigmodon hispidus	cotton rat	F	yes	
Geomyidae		**Pocket Gophers**			
	Geomys bursarius	plains pocket gopher	V	yes	
Heteromyidae		**Pocket Mice and Kangaroo Rats**			
	Perognathus hispidus	hispid pocket mouse	F	yes	
Muridae		**Old World Rats and Mice**			
	Mus musculus	house mouse	V	yes	
	Rattus norvegicus	Norway rat	F	yes	
	Rattus rattus	black rat	F	yes	
Sciuridae		**Squirrels**			
	Glaucomys volans	southern flying squirrel	F	yes	
	Sciurus carolinensis	gray squirrel	F	yes	
	Sciurus niger	fox squirrel	F	yes	

Appendix A.3: Reptile and amphibian species of BLHF and BITH.

Order (Suborder) Family	Scientific name	Common name	BLHF stat.[11]	BITH pres.[12]	T&E stat.[13]
Anura					
Bufonidae		**Toads**			
	Bufo valliceps	Gulf Coast toad	F	yes	
	Bufo woodhousii	Woodhouse's toad		yes	
Hylidae		**Treefrogs**			
	Acris crepitans crepitans	northern cricket frog	F	yes	
	Hyla avivoca	bird-voiced treefrog	F	yes	
	Hyla cinerea	green treefrog	F	yes	
	Hyla squirella	squirrel treefrog	F	yes	
	Hyla versicolor chrysoscelis	gray treefrog	F	yes	
	Pseudacris crusifer	spring peeper	F	yes	
	Pseudacris nigrita	southern chorus frog	F		
	Pseudacris streckeri	Strecker's chorus frog		yes	
	Pseudacris triseriata	upland chorus frog	F	yes	
Microhylidae		**Narrow-mouthed Toads**			
	Gastrophryne carolinensis	eastern narrow-mouthed toad	F	yes	
	Gastrophryne olivacea	Great Plains narrow-mouthed frog	yes		
Pelobatidae		**Spadefoot Toads**			
	Scaphiopus holbrooki	spadefoot toad	F	yes	
Ranidae		**Aquatic Frogs**			
	Rana areolata	crawfish frog		yes	
	Rana catesbeiana	bullfrog	F	yes	
	Rana clamitans clamitans	bronze frog	F	yes	
	Rana clamitans melanota	green frog	F		
	Rana grylio	pig frog		yes	
	Rana heckscheri	river frog	F		

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[11] Type of use of bottomland hardwood forest was determined from BTNP surveys (see below) and general literature on BLHF including Patrick *et al.* (1981), Wharton et al. (1982), Schmidly (1983), Frentress (1986), Mitsch and Gosselink (1986), Fritzel (1988), Lea (1988), Niering (1988), and Ernst and Brown (1989).

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[12] Presence in BTNP was determined from BTNP surveys and general literature on BITH including Rainwater (1974), Fisher and Rainwater (1978), and Halstead (1981).

[13] Federal endangered status was taken from USF&WS Report to Congress: Endangered and Threatened Species Recovery Program. Texas endangered status taken from TP&WD Endangered Resources Annual Status Report.

E = Endangered T = Threatened
C2, etc. refers to federal status. These species are being considered for listing.

Appendix A.3: Reptile and amphibian species of BLHF and BITH (continued).

Order (Suborder) Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
	Rana palustris	pickerel frog		yes	
	Rana pipiens sphenocephala	northern leopard frog		yes	
	Rana utricularia	southern leopard frog	F	yes	
Caudata					
Ambystomatidae		**Mole Salamanders**			
	Ambystoma cingulatum	flatwoods salamander	F		
	Ambystoma maculatum	large spotted salamander	F	yes	
	Ambystoma opacum	marbled salamander	F	yes	
	Ambystoma talpoideum	mole salamander	F	yes	
	Ambystoma texanum	small-mouthed salamander		yes	
Amphiumidae		**Giant Salamanders**			
	Amphiuma means	two-toed amphiuma	F	yes	
	Amphiuma tridactylum	three-toed amphiuma		yes	
Plethodontidae		**Lungless Salamanders**			
	Desmognathus auriculatus	southern dusky salamander	F	yes	
	Eurycea bislineata	northern two-lined salamander	F		
	Eurycea quadridigitata	dwarf salamander	F	yes	
	Hemidactylium scutatum	four-toed salamander	F		
	Plethodon cinereus	redback salamander	F		
	Plethodon glutinosus	slimy salamander	F		
	Pseudotriton montanus	mud salamander	F		
	Pseudotriton ruber	red salamander	F		
	Stereochilus marginatus	many-lined salamander	F		
Proteidae		**Mudpuppies and Waterdogs**			
	Necturus beyeri	Gulf Coast waterdog		yes	
Salamanidae		**True Salamanders**			
	Notophthalmus viridescens	central newt	F	yes	
Sirenidae		**Sirens**			
	Siren intermedia	lesser siren	F	yes	
Chelonia (Cryptodira)		**Turtles**			
Chelydridae		**Snapping Turtles**			
	Chelydra serpentina	snapping turtle	F	yes	
	Macroclemys temminckii	alligator snapping turtle	F	yes	
Emydidae		**Semiaquatic Pond and Marsh Turtles**			
	Deirochelys reticularia	chicken turtle	O	yes	
	Graptemys kohnii	Mississippi map turtle	F	yes	
	Graptemys oculifera	ringed map turtle	F	yes	

Appendix A.3: Reptile and amphibian species of BLHF and BITH (continued).

Order (Suborder) Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
	Graptemys pseudogeographica	false map turtle	F	yes	
	Pseudemys concinna	eastern river cooter	F	yes	
	Terrapene carolina major	Gulf Coast box turtle	F	yes	
	Terrapene carolina triunguis	three-toed box turtle	F	yes	
	Terrapene ornata ornata	ornate box turtle	F	yes	
	Trachemys floridana	Missouri slider	F	yes	
	Trachemys scripta elgans	red-eared slider	F	yes	
Kinosternidae		**Musk and Mud Turtles**			
	Kinosternon subrubrum	eastern or Mississippi mud turtle	F	yes	
	Sternotherus carinatus	razorback musk turtle	F	yes	
	Sternotherus odoratus	stinkpot or common musk turtle	F	yes	
Trionychidae		**Soft-shelled Turtles**			
	Apolone mutica	smooth softshell turtle	F	yes	
	Apolone spinifera	spiny softshell turtle	F	yes	
Crocodylia					
Alligatoridae		**Alligators**			
	Alligator mississippiensis	American alligator		yes	
Squamata (Lacertilia)		**Iguanids**			
Anguididae		**Glass and Alligator Lizards**			
	Ophisaurus attenuatus	slender glass lizard		yes	
Phrynosomatidae		**Spiny and Horned Lizards**			
	Phrynosoma cornutum	Texas horned lizard		yes	C2,T
	Sceloporus undulatus	eastern fence lizard		yes	
Polychridae		**American Arboreal Lizards**			
	Anolis carolinensis	green anole	F	yes	
Scincidae		**Skinks**			
	Eumeces fasciatus	five-lined skink	F	yes	
	Eumeces inexpectatus	southeastern five-lined skink	F	yes	
	Scincella lateralis	ground skink	F	yes	
Teiidae		**Whiptails**			
	Cnemidophorus sexlineatus	six-lined racerunner		yes	
(Serpentes)		**Snakes**			
Colubridae		**Colubrids**			
	Cemophora coccinea	scarlet snake		yes	

Appendix A.3: Reptile and amphibian species of BLHF and BITH (continued).

Order (Suborder) Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
	Coluber constrictor	black racer	F	yes	
	Coluber constrictor anthicus	buttermilk racer		yes	
	Diadophis punctatus strictogenys	Mississippi ringneck snake		yes	
	Elaphe guttata emoryi	Great Plains rat snake	F	yes	
	Elaphe obsoleta	Texas (or black) rat snake	F	yes	
	Farancia abacura	mud snake	F	yes	
	Heterodon platirhinos	eastern hognose snake	F	yes	
	Lampropeltis calligaster	prairie kingsnake		yes	
	Lampropeltis getula	speckled kingsnake	F	yes	
	Lampropeltis triangulum amaura	Louisiana milk snake	F	yes	yes
	Masticophis flagellum	eastern coachwhip snake	F	yes	
	Nerodia cyclopion	green water snake		yes	
	Nerodia erythrogaster erythrogaster	red-bellied water snake	F	yes	
	Nerodia erythrogaster neglecta	copperbelly water snake	F		
	Nerodia fasciata confluens	broad-banded water snake	F	yes	
	Nerodia rhombifer	diamondback water snake	F	yes	
	Nerodia rigida	gulf glossy water snake	F	yes	
	Nerodia taxispilota	brown water snake	F		
	Opheodrys aestivus	rough green snake	F	yes	
	Pituophis melanoleucus ruthveni	Louisiana pine snake		yes	C2,E
	Regina grahamii	Graham's crayfish snake		yes	
	Regina rigida	glossy crayfish snake		yes	
	Storeria dekayi texana	Texas brown snake	F	yes	
	Storeria occipitomaculata	redbelly snake	F	yes	
	Tantilla gracilis	flathead snake		yes	
	Thamnophis proximus orarius	Gulf Coast ribbon snake		yes	
	Thamnophis sauritus	western ribbon snake	F	yes	
	Thamnophis sirtalis annectens	eastern garter snake	F	yes	C2,-
	Virginia striatula	rough earth snake		yes	
Elapidae		**Coral Snakes**			
	Micrurus fulvius	eastern coral snake			
Viperidae		**Pit Vipers**			
	Agkistrodon contortrix	southern copperhead	F	yes	
	Agkistrodon piscivorus	western cottonmouth	F	yes	
	Crotalus horridus	canebrake or timber rattlesnake	F	yes	G5,T
	Sistrurus miliarius stracheri	western pygmy rattlesnake		yes	

Appendix A.4: Fish species of BLHF and BITH.

Order / Family	Scientific name	Common name	BLHF stat.[14]	BITH pres.[15]	T&E stat.[16]
Acipenseriformes					
Polyodontidae		**Paddlefishes**			
	Polyodon spathula	American paddlefish		yes	-, E
Amiiformes					
Amiidae		**Bowfins**			
	Amia calva	bowfin	F	yes	
Anguilliformes					
Anguillidae		**True Eels**			
	Anguilla rostrata	American eel	F	yes	
Ophichthidae					
	Myrophis punctatus	spackled worm eel		yes	
Atheriniformes					
Atherinidae		**Silversides**			
	Labidesthes sicculus	brook silverside		yes	
	Menidia beryllina	inland silverside		yes	
Belonidae		**Needlefishes**			
	Strongylura marina	Atlantic needlefish	F		
Cyprinodontidae		**Topminnows**			
	Fundulus blairae	Blair's topminnow		yes	
	Fundulus chrysotus	golden topminnow		yes	
	Fundulus notatus	blackstripe topminnow		yes	
	Fundulus olivaceus	blackspotted topminnow		yes	
	Lucania parva	rainwater killfish	F	yes	

[14] Type of use of bottomland hardwood forest was determined from BTNP surveys (see below) and general literature on BLHF including Patrick *et al.* (1981), Wharton et al. (1982) , Schmidly (1983), Mitsch and Gosselink (1986), Frentress (1986), Lea (1988), Niering (1988), Fritzel (1988), Ernst and Brown (1989), and Seidensticker (1994).

O = Obligate inhabitant of bottomland hardwood forest.
F = Facultative inhabitant of bottomland hardwood forest.
V = Occasional Visitor to bottomland hardwood forest.

[15] Presence in BTNP was determined from BTNP surveys and general literature on BITH including Eschelle (1974), Harrel and Watson (1975), Harrel (1976), Clemmer (1977), Suttkus and Clemmer (1979), and Halstead (1981).

[16] Federal endangered status was taken from USF&WS Report to Congress: Endangered and Threatened Species Recovery Program. Texas endangered status taken from TP&WD Endangered Resources Annual Status Report.

E = Endangered T = Threatened
C2, etc. refers to federal status. These species are being considered for listing.

Appendix A.4: Fish species of BLHF and BITH (continued).

Order Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
Poeciliidae		**Tooth-carps, Killfishes, and Minnows**			
	Gambusia affinis	mosquitofish	F	yes	
	Heterandria formosa	least killfish	F		
Clupeiformes					
Clupidae		**Herrings**			
	Alosa aestivalis	blueback herring	F		
	Alosa mediocris	hickory shad	F		
	Alosa sapidissima	American shad	F		
	Dorosoma cepedianum	gizzard shad		yes	
	Dorosoma petenense	threadfin shad		yes	
Cypriniformes					
Catostomidae		**Suckers**			
	Carpiodes carpio	river carpsucker		yes	
	Cycleptus elongatus	blue sucker		yes	
	Erimyzon oblongus	creek chubsucker	F	yes	-, T
	Erimyzon sucetta	lake chubsucker	F	yes	
	Ictiobus bubalus	smallmouth buffalo		yes	
	Ictiobus cyprinellus	bigmouth buffalo		yes	
	Ictiobus niger	black buffalo		yes	
	Minytrema melanops	spotted sucker		yes	
	Moxostoma poecilurum	blacktail redhorse		yes	
Cyprinidae		**Carp and Minnows**			
	Cyprinus carpio	common carp		yes	
	Hybognathus nuchalis	Mississippi silvery minnow		yes	
	Hybopsis aestivalis	speckled chub		yes	
	Hybopsis amnis	pallid chub		yes	
	Notemigonus crysoleucas	golden shiner	F	yes	
	Notropis atherinoides	emerald shiner		yes	
	Notropis atrocaudalis	blackspot shiner		yes	
	Notropis buchanani	ghost shiner		yes	
	Notropis chalybaeus	ironcolor shiner		yes	
	Notropis emiliae	pugnose minnow		yes	
	Notropis fueus	ribbon shiner		yes	
	Notropis lutrensis	red shiner		yes	
	Notropis lutrensis X Notropis venustus	red and blacktail shiner hybrid		yes	
	Notropis sabinae	sabine shiner		yes	
	Notropis shumardi	silverband shiner		yes	
	Notropis texanus	weed shiner		yes	
	Notropis umbratilis	redfin shiner		yes	

Appendix A.4: Fish species of BLHF and BITH (continued).

Order / Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
	Notropis venustus	blackfin shiner		yes	
	Notropis volucellus	mimic shiner		yes	
	Phenacobius mirabilis	suckermouth minnow		yes	
	Pimephales vigilax	bullhead minnow		yes	
	Semotilus atromaculatus	creek chub		yes	
Perciformes					
Centrarchidae		**Sunfishes**			
	Centrarchus macropterus	flier	F	yes	
	Chaenobryttus gulosus	warmouth			
	Elassoma zonatum	banded pygmy sunfish	F		
	Enneacanthus gloriosus	bluespotted sunfish	F		
	Enneacanthus obesus	banded sunfish	F		
	Lepomis auritus	redbreast sunfish	F	yes	
	Lepomis cyanellus	green sunfish	F	yes	
	Lepomis gibbosus	pumpkinseed	F	yes	
	Lepomis gulosus	warmouth	F	yes	
	Lepomis macrochirus	bluegill	F	yes	
	Lepomis marginatus	dollar sunfish		yes	
	Lepomis megalotis	longear sunfish		yes	
	Lepomis microlophus	redear sunfish	F	yes	
	Lepomis puntcatus	spotted sunfish		yes	
	Lepomis symmerticus	bantam sunfish		yes	
	Micropterus punctulatus	spotted bass		yes	
	Micropterus salmoides	largemouth bass		yes	
	Pomoxis annularis	white crappie		yes	
	Pomoxis nigromaculatus	black crappie		yes	
Mugilidae		**Mullets**			
	Mugil cephalus	striped mullet	F	yes	
Percichthyidae		**White Basses**			
	Morone chrysops	white bass		yes	
Percidae		**Perches**			
	Ammocrypta clara	western sand darter		yes	
	Ammocrypta vivax	scaly sand darter		yes	
	Etheostoma asprigene	mud darter		yes	
	Etheostoma chlorosomum	bluntnose darter		yes	
	Etheostoma fusiforme	swamp darter	F	yes	
	Etheostoma gracile	slough darter		yes	
	Etheostoma histrio	harlequin darter		yes	
	Etheostoma parvipinne	goldstripe darter		yes	
	Etheostoma proelaire	cypress darter		yes	
	Etheostoma whipplei	redfin darter		yes	

Appendix A.4: Fish species of BLHF and BITH (continued).

Order / Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
	Percina macrolepida	bigscale logperch		yes	
	Percina sciera	dusky darter		yes	
	Percina shumardi	river darter		yes	
Sciaenidae		**Croakers**			
	Alpodinotus grunniens	freshwater drum		yes	
Serranidae		**Black Basses**			
	Centropristis striata	black sea bass	F		
Percopsiformes					
Aphredoderidae		**Pirate Perches**			
	Aphredoderus sayanus	pirate perch	F	yes	
Petromyzontiformes					
Petromyzontidae		**Lampreys**			
	Ichthyomyzon castaneus	chestnut lamprey		yes	
	Ichthyomyzon gagei	southern brook lamprey		yes	
Pleuronectiformes					
Bothidae		**Lefteye Flounders**			
	Paralichthys lethostigma	southern flounder	F		
Soleidae		**Soles and Tonguefishes**			
	Trinectes maculatus	hogchoker	F	yes	
Salmoniformes					
Esocidae		**Pikes**			
	Esox americanus	redfin pickerel	F	yes	
	Esox niger	chain pickerel	F		
Semionotiformes					
Lepisosteidae		**Gar Pikes**			
	Lepisosteus oculatus	spotted gar		yes	
	Lepisosteus osseus	longnose gar		yes	
	Lepisosteus spatula	alligator gar		yes	

Appendix A.4: Fish species of BLHF and BITH (continued).

Order	Family	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
Siluriformes						
	Ictaluridae		**Catfishes**			
		Ictalurus furcatus	blue catfish		yes	
		Ictalurus melas	black bullhead		yes	
		Ictalurus natalis	yellow bullhead	F	yes	
		Ictalurus nebulosus	brown bullhead	F		
		Ictalurus punctatus	channel catfish		yes	
		Noturus gyrinus	tadpole madtom		yes	
		Noturus nocturnus	freckled madtom		yes	
		Pylodictis olivaris	flathead catfish		yes	

Appendix A.5: Invertebrate species of BLHF and BITH.

Phylum (Subphlyum)	Class (Order)	Scientific name	Common name	BLHF stat.[17]	BITH pres.[18]	T&E stat.[19]
Annelida						
	Hirudinae					
		Helobdella fusca	leech			
		Placobdella papillifera	leech			
		Placobdella parasitica	leech			
	Oligochaeta					
		Allolobophora	earthworm	F		
		Aulodrilus pluriseta	tubificid worm			
		Dero	naidid worm			
		Diplocardia	earthworm	F		
		Eisenia	earthworm	F		
		Helodrilus	earthworm	F		
		Limnodrilus hoffmeisteri	oligochaete worm			
		Peloscolex multisetosus	tubificid worm	F		
		Sparganophilus	earthworm	F		
Arthropoda (Chelicerata)						
	Arachnida					
		Dolomedes	fishing spider	F		
		Hydrozetes	oribatid mite	F		
		Lycosa helluo	wolf spider	F		
		Micrathena gracilis	spinyback spider	F		

[17] Type of use of bottomland hardwood forest was determined from BTNP surveys (see below) and general literature on BLHF i Patrick *et al.* (1981), Wharton et al. (1982) , Schmidly (1983), Frentress (1986), Mitsch and Gosselink (1986), Fritzel (1988), L (1988), Niering (1988), and Ernst and Brown (1989).
O = Obligate inhabitant of bottomland hardwood forest.
F = Facultative inhabitant of bottomland hardwood forest.
V = Occasional visitor to bottomland hardwood forest.

[18] Presence in BTNP was determined from BTNP surveys and general literature on BITH including Patterson (1971), Ashcraft (1973), Howard (1973), McCollough (1974), Kost (1977), Darville (1978), Harrel and Darville (1978), Bass (1979), Harrel and Bass (1979), Harrel and Commander (1980), and Harcombe and Hughes (1982).

[19] Federal endangered status was taken from USF&WS Report to Congress: Endangered and Threatened Species Recovery Program. Texas endangered status taken from TP&WD Endangered Resources Annual Status Report.
E = Endangered T = Threatened
C2, etc. refers to federal status. These species are being considered for listing.

Appendix A.5: Invertebrate species of BLHF and BITH (continued).

Phylum (Subphlyum)	Class (Order)	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
		Neoscona arabesca	orb weaver spider	F		
		Pirata maculatus	fishing spider	F		
		Schizocosa crassipes	wolf spider	F		
		Schizocosa ocreata	wolf spider	F		
(Crustacea)						
	Malacostraca					
	(Amphipoda)					
		Gammarus tigrinus	amphipod	F		
		Hyalella azteca	amphipod	F		
	(Decapoda)					
		Cambarus diogenes	crayfish	F		
		Fallicambarus uhleri	crayfish	F		
		Macrobrachium ohione	River shrimp			
		Palaemonetes kadiakensis	freshwater shrimp			
		Palaemonetes paludosa	grass shrimp			
		Procambarus acutus	crayfish	F		
		Procambarus clarki	red swamp crayfish			
		Procambarus clarkii	red crayfish	F		
		Procambarus pubischelae	crayfish	F		
		Procambarus seminolae	crayfish	F		
		Procambarus troglodytes	crayfish	F		
		Sesarma	square-backed crab	F		
	(Isopoda)					
		Asellus	isopod	F		
		Lirceus lineatus	isopod	F		
(Unirama)						
	Diplopida					
		Cherokia georgiana	millipede	F		
		Narceus americana	millipede	F		
	Insecta					
	(Coleptera)					
		Abacidus	carabid beetle	F		
		Carabus	carabid beetle	F		
		Dineutus assimilis	whirligig beetle	F		
		Heterocerus brunneus	varigated mud-loving beetle		yes	
		Heterocerus pustillius	varigated mud-loving beetle		yes	
		Heterocerus undatus	varigated mud-loving beetle		yes	
		Laccophilus proximus	predaceous diving beetle		yes	
		Macronychus glabratus	rifle beetle		yes	

Appendix A.5: Invertebrate species of BLHF and BITH (continued).

Phylum (Subphlyum)	Class (Order)	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
		Matus bicarinatus	predaceous diving beetle		yes	
		Onthophagus	scarab	F		
		Termonecites basilaris	predaceous diving beetle		yes	
	(Diptera)					
		Chaoborus punctipennis	phantom midge larva	F		
		Chauliodes rastricornis	fish fly		yes	
		Chironomidae	midge fly larva	F		
		Chironomus	chironomid			
		Coelptanypus	midge fly			
		Crytochironomus	chironomid midge fly			
		Harnischia	chironomid midge fly			
		Palpomyia	ceratopogonid biting midge			
		Tanytarsus	chironomid midge fly			
	(Ephemeroptera)					
		Caenis	mayfly	F		
	(Hemiptera)					
		Curcita howardi	water scorpion		yes	
		Gerris marginatus	water strider		yes	
		Gerris remigis	water strider		yes	
		Lethocerus griseus	giant water bug		yes	
		Neoplea striola	back swimmer	F		
		Pentacora signoreti	shore bug		yes	
		Sigara alternata	water boatman		yes	
	(Lepidoptera)					
		Asterocampa celtis	hackberry butterfly	F		
		Euptychia hermes sosybia	Carolina satyr butterfly	F		
		Libytheana bachmanii	snout butterfly	F		
		Limenitis arthemis astaynax	red spotted purple butterfly	F		
		Papilio marcellus	zebra swallowtail butterfly	F		
		Phyciodes tharos	pearl crescent butterfly	F		
	(Neuroptera)					
		Corydalus cornutus	Dobson fly		yes	
	(Odonata)					
		Calopteryx maculata	black-winged damsel fly		yes	
		Enallagma	damsel fly	F		
		Epiaeschna heros	dragonfly	F		
		Gomphus exilis	dragonfly	F		
		Ischnura	damsel fly		yes	
		Pachydiplax Longipennis	blue pirate		yes	
		Tetragoneuria cynasura	dragonfly	F		

Appendix A.5: Invertebrate species of BLHF and BITH (continued).

Phylum (Subphlyum)	Class (Order)	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
	(Orthoptera)					
		Ceuthophilus gracilipes	camel cricket	F		
		Pterophylla camellifolia	katydid	F		
		Scudderia rhombifolium	katydid	F		
	(Trichoptera)					
		Phylocentropus	caddis fly			
Cnidaria						
	Hydroza					
		Hydra americana	coelenterata			
Ectoprocta						
	Phylactolaemata					
		Fredericella sultana	bryozoan			
		Paludicella articulata	bryozoan			
		Plumatella repens	bryozoan			
Mollusca						
	Gastropoda					
		Campeloma	snail	F		
		Ferrissia	snail	F		
		Haplotrema concavum	cannibal snail	F		
		Lioplax	snail	F		
		Mesodon thyroidus	white-lipped forest snail	F		
		Mesomphix vulgatus	great zonite snail	F		
		Neritina reclivata	olive nerite snail	F		
		Physa	pulmonate snail	F		
		Pomacea paludosa	apple snail			
		Promenetus	snail	F		
	Pelecypoda					
		Anodonta	clam	F		
		Corbicula	clam	F		
		Eupera	fingernail clam	F		
		Ligumia	clam	F		
		Mercenaria mercenaria	hard clam	F		
		Musculium	sphaeriid clam	F		
		Pisidium	finger clam	F		
		Sphaerium	sphaeriid clam	F		
		Sphaerium partumeium	fingernail clam	F		

Appendix A.5: Invertebrate species of BLHF and BITH (continued).

Phylum (Subphlyum)	Class (Order)	Scientific name	Common name	BLHF stat.	BITH pres.	T&E stat.
Platyhelminthes						
	Turbellaria					
		Dugesia tigrina	flatworm			
		Planaria	flatworm			
Porifera						
	Demospongiae					
		Spongilla fragilis	sponge			
		Trochospongilla horridus	sponge			
Rotifera						
		Rotatoria (phylum)	rotifers	F		

Appendix B: State and/or Federally listed (Endangered, Threatened, and Candidate) Species of Big Thicket National Preserve (BTNP) and vicinity.

The following pages contain a list of endangered, threatened, and candidate species of the BTNP that was constructed as follows:

(1) State and/or federally listed (endangered, threatened, or candidate status) species in the seven county area around the BTNP were listed (TPWD 1993c&d, USFWS 1993a.

(2) State and federally listed species present or potentially present in the BTNP according to species lists in each chapter of this report were added.

(3) 'Bottomland hardwood forest' (BLHF) status (references in footnotes of species lists in each chapter of this report) was included to indicate likelihood of presence in the water corridors.

(4) Descriptions of specific locations in the BTNP according to the Texas Natural Heritage Program (TPWD 1994) were added.

(5) Relevant G. Watson notes (1982) on species locations in BTNP units were added.

Legend

Status or rank codes : **E** = endangered, **T** = threatened, **C1** = candidate species for federal listing; category 1, substantial data supports state of vulnerability, **C2** = candidate species for federal listing; category 2, some but less substantial data indicate vulnerability; **3C** = species no longer being considered for federal listing, **NL** = not listed, **S1** = < 6 occurrences in Texas, critically imperiled in the state, **S2** = 6-20 occurrences in Texas, imperiled, **S3** = 21-100 occurrences in Texas, rare or uncommon, **S4** = >100 occurrences in Texas, apparently secure, **S5** = demonstrably secure in Texas, **SX** = presumed extirpated Texas (From USFWS 1989 and TPWD 1991).

County codes : **H** = Hardin, **Ja** = Jasper, **Je** = Jefferson, **P** = Polk, **T** = Tyler, **O** = Orange, **L** = Liberty

Bottomland hardwood forests (BLHF) status codes : **O** = Obligate inhabitant of BLHF, **F** = Facultative inhabitant of BLHF, **V** = Occasional visitor to BLHF.

Appendix B: State and/or Federally listed (Endangered, Threatened, and Candidate) Species of BTNP and vicinity (continued).

Scientific name	Common name	BLHF status	Fed./State status	County distrib.

PLANTS

Family Apiaceae

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
Oxypolis ternata	three-leaf cowbane		C2,S1	H,T

Family Apocynaceae

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
Amsonia glabberima	smooth blue-star		3C,S2	

BTNP location - Beaumont Unit, 1.0 air miles north of the Lower Neches Valley Authority Canal Pumping Station along Pine Island Bayou.

Family Brassicaceae

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
Armoracia lacustris	lady cress	F	C2,S1	T

Family Caryophyllaceae

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
Silene subciliata	scarlet catchfly	F	E,S3	H,Ja,Je, L,P,T

BTNP locations:

(1) Menard Creek Corridor Unit, Big Sandy Creek Unit, between 2 bridges over Menard Creek on FM 943,
(2) Lance Rosier Unit, exposed sand surfaces of old stream levee deposits,
(3) near Big Sandy Creek Unit-ca. 300' west of NW corner of BSC unit in Alabama-Coushatta Indian Reservation, along foot trail through dense re-growth from clear-cut,
(4) Menard Creek Corridor Unit, near parking lot on SE bank of Menard Creek, both sides of unnamed road that crosses creek near Hardin-Liberty county line, fairly well-drained sandy flat at margin of forest,
(5) Turkey Creek Unit, both sides of Hester Bridge Road, 0.5 miles west of its crossing of Turkey Creek,
(6) Menard Creek Unit, east side of north-south road to Fuqua, just south of bridge over Menard Creek,
(7) Big Sandy Creek Unit, along "Woodlands Trail" ca. 1/10 mile east of parking lot on FM 1276.

G. Watson - At edge of sandhills and terraces. Few individuals widely scattered in Turkey Creek & Big Sandy Units. Once in Lance Rosier Unit. Locations in Big Sandy & Lance Rosier Units now gone (fire responsive, must have open sun).

Family Compositae

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
Gaillardia aestivalis var. *winkleri*	white firewheel	F	C2,S1	H
Prenanthes barbata	rattlesnake root	F	C2,S2	H,Ja

BTNP location - Neches Bottom & Jack Gore Baygall Units, Sally Withers Lake area, sandy slope in mixed woods.

G. Watson - C&J "rare in sandy, forested areas of east Texas. Few individuals along small streams at edge of savannas." Two found at edge of sandhill by Sally Withers Lake in Upper Neches

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
Liatris tenuis	slender gay-feather	F	C2,S3	Ja,T

G. Watson - few found in Big Sandy Unit

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
Rudbeckia scabrifolia	bog coneflower	F	C2,S2	Ja

Appendix B: State and/or Federally listed (Endangered, Threatened, and Candidate) Species of BTNP and vicinity (continued).

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
Family Cyperaceae				
Cyperus grayoides	Mohlenbrock's umbrella sedge	F	C2,S3	H,T
	BTNP location - Turkey Creek Unit, w/in 20' of property fence line at 75° angle from fence. ca. 0.5 air mile due east of junction of Turkey & Village Creeks.			
Family Eriocaulaceae				
Lachnocaulon digynum	bog buttons	F	C2,S1	Ja
Eriocaulon kornickianum	small-headed pipewort	F	C2,S1	T
	G. Watson - found in Turkey Creek Unit in 1960's, not seen since.			
Family Gentianaceae				
Bartonia texana	Texas screwstem	O	3C,S2	H,Ja,P,T
	BTNP locations - (1) Neches Bottom & Jack Gore Baygall Units, NNE of Silsbee, (2) Turkey Creek Unit, edge of savannah.			
Family Labiatae				
Physostegia longisepala	long-sepaled false dragonhead	F	C2,S2	H,Ja,O
Family Liliaceae				
Trillium pusillum var. *texanum*	Texas (least) trillium	O	C2,S3	T
Family Orchidaceae				
Spiranthes parksii	Navasota ladies-tresses	O	E,S3	Ja
Cypripedium kentuckiense	southern lady's slipper	F	C2,S1	T
Family Polemoniaceae				
Phlox nivalis var. *texensis*	Texas trailing phlox		E,E	H,P,T
	BTNP locations- (1) Big Sandy Creek Unit, sandy uplands, (2) Turkey Creek Unit, NNE of confluence of Village & Turkey Creeks, & east of Turkey Creek. G. Watson- Sandhills in Turkey Creek & Big Sandy Units			
Family Rosaceae				
Agrimonia incisa	harvest lice	F	C2,S1	Ja
Family Xyridaceae				
Xyris drummondii	Drummond's yellow-eyed grass	F	C2,S2	Ja
Xyris scabrifolia	rough-leaf yelllow-eyed grass	F	C2,S2	Ja

Appendix B: State and/or Federally listed (Endangered, Threatened, and Candidate) Species of BTNP and vicinity (continued).

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
AMPHIBIANS				
Order Anura				
Family Bufonidae				
Bufo houstonensis	Houston toad		E,E	L
BIRDS				
Family Ciconiidae				
Mycteria americana	wood stork	F	-,T	
Family Pelecanidae				
Pelecanus occidentalis	brown pelican	V	E,E	Je
Family Accipitridae				
Haliaeetus leucocephalus	bald eagle	F	T,E	H,Ja,Je,L,O,P,T
Family Falconidae				
Falco peregrinus tundrius	Arctic peregrine falcon	V	T,T	Je
Family Scolopacidae				
Numenius borealis	eskimo curlew	V	E,E	
Numenius americanus	long-billed curlew	V	C2,NL	Je,L
Family Picidae				
Campephilus principalis	ivory-billed woodpecker	O	E,E	
Picoides borealis	red-cockaded woodpecker BTNP location - Big Sandy Creek Unit - 4.2 km. south of dam at Lake Tombigbee, Polk Co.	V	E,E	H,Ja,L,P,T
Family Vireonidae				
Vireo bellii	Bell's vireo	V	E,E	
Vermivora bachmanii	Bachman's warbler	O	E,E	
Family Fringillidae				
Aimophila aestivalis	Bachman's sparrow	F	C2,T	H,Ja,Je,L,O,P,T
Ammodramus henslowii	Henslow' sparrow	V	C2,SX	H,L

Appendix B: State and/or Federally listed (Endangered, Threatened, and Candidate) Species of BTNP and vicinity (continued).

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
Family Charadriidae				
Charadrius melodus	piping plover	V	T,T	Je
Charadrius alexandrinus tenuirostris	southeastern snowy plover	V	C2,S2	Je
tFamily Threskiornithidae				
Plegadis chihi	white-faced ibis	V	C2,S2	Je,O
Family Ardeidae				
Egretta rufescens	reddish egret	V	C2,S2	Je
Family Meleagrididae				
Meleagris gallpavo	wild turkey	F	NL,NL	*

County distributions were taken from inventories of state or federally-listed species which the wild turkey is not. However, it was included here because although it is not threatened on a state or national scale, it was nearly extirpated from east Texas by 1900 and is presently being restocked (Campo and Dickson 1990).

MAMMALS

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
Order Chiroptera				
Family Vespertilionidae				
Myotis austroriparius	southeastern bat	O	C2,T	H, L,T
Plecotus rafinesquii	Rafinesque's big-eared bat	F	C2,T	H,P
Order Carnivora				
Family Mustelidae				
Conepatus mesoleucus telmalestes	Big Thicket hog-nosed skunk	F	C2,S1	H, L
Spilogale putorius interupta	Plains spotted skunk	F	C2,NL	L,O
Family Ursidae				
Ursus Americanus	Black Bear	F	T(S/A), E	

FISH

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
Order Acipenseriformes				
Family Poltodontidae				
Polyodon spathula	paddlefish	F	C2,E	

Appendix B: State and/or Federally listed (Endangered, Threatened, and Candidate) Species of BTNP and vicinity (continued).

Scientific name	Common name	BLHF status	Fed./State status	County distrib.
Order Cypriniformes				
Family Catostomidae				
Erimyzon oblongus	creek chubsucker	F	NL,T	
CLASS REPTILIA[20]				
Order Squamata				
Suborder Serpentes				
Family Colubridae				
Thamnophis sirtalis annectens	Texas garter snake	F	C2,-	
Pituophis melanoleucus ruthveni	Louisiana pine snake BTNP location - Menard Creek & Big Sandy Creek Units	F	C2,E	H,Ja,P,T
Family Viperidae **Subfamily Crotalinae**				
Crotalus horridus	timber/canebreak rattlesnake	F	G5,T	
Suborder Lacertilia				
Family Phrynosomatidae				
Phrynosoma cornutum	Texas horned lizard		C2,T	Je,L,O
Order Chelonia				
Suborder Cryptodira				
Family Chelydridae **Subfamily Chelydridae**				
Macroclemys temmincki	Alligator snapping turtle		C2,S3	H,Ja,Je,L,O,P,T
Family Emydidae				
Malaclemys terrapin littoralis	Texas diamondback terrapin		C2,S3	Je,L,O

INVERTEBRATES
None listed

[20] Sea turtles and salt marsh snake, which were on county lists, were omitted because there is no appropriate habitat in BTNP.

Appendix C: White-tailed Deer Harvest and Survey Data

White-tailed deer harvest and survey data from Big Thicket National Park (BTNP 1993) and the Texas Parks and Wildlife Department (TPWD 1993a, Boydston 1993, and Karns 1993) were used to compile these tables for comparison of general population trends within BTNP and the surrounding area. Records are compiled annually by NPS.

Table C.1: Deer Hunter Success in BTNP from 1984-93, by year (in percentage) (BTNP 1993).

Unit	92-93	91-92	90-91	89-90	88-89	87-88	86-87	85-86	84-85
Beaumont	NA	NA	NA	22	35	21	16	12	NA
Beech Creek	NA	NA	NA	13	19	19	0	1	4
Big Sandy	NA	NA	NA	26	36	32	19	15	12
Neches Bottom	NA	NA	NA	31	35	20	20	6	9
Jack Gore Baygall	NA	NA	NA	35	22	13	10	8	4
Lance Rosier	NA	NA	NA	9	17	12	8	6	6

NA=Not Available

Table C.2: Number of Deer Harvested in BTNP from 1984-93, by year (BTNP 1993).

Unit	92-93	91-92	90-91	89-90	88-89	87-88	86-87	85-86	84-85
Beaumont	63	48	57	30	75	22	29	10	NA
Beech Creek	9	30	16	17	19	16	0	2	12
Big Sandy	84	84	113	97	154	105	83	37	64
Neches Bottom	33	38	104	33	46	11	24	3	7
Jack Gore Baygall	71	68	128	64	92	41	34	16	26
Lance Rosier	89	60	79	60	149	82	65	28	57
BTNP Total	**349**	**328**	**497**	**301**	**535**	**277**	**235**	**96**	**166**

Appendix C: White-tailed Deer Harvest and Survey Data (continued).

Table C.3: White-tailed Deer Hunter Success in East Texas from 1987-93, by year (in percentage) (TPWD 1993a and Boydston 1993).

County	92-93	91-92	90-91	89-90	88-89	87-88
Jasper	NA	40	45	45	43	33
Tyler	NA	54	43	53	48	43
Polk	NA	45	37	58	50	54
Hardin	NA	33	40	48	52	34

NA=Not Available

Table C.4: Number of White-tailed Deer Harvested in East Texas from 1987-93, by year (TPWD 1993a and Boydston 1993).

County	92-93	91-92	90-91	89-90	88-89	87-88
Jasper	3726	2825	2805	3657	2906	1872
Tyler	4118	5761	3083	4205	3977	3778
Polk	4778	5132	3638	6464	6786	6127
Hardin	5174	2476	2476	2476	4177	3206

Table C.5: White-tailed Deer per 1000 acres from 1988-92, as determined by spotlight survey (Karns 1993).

County	1992 #/1000 acres	1991 #/1000 acres	1990 #/1000 acres	1989 #/1000 acres	1988 #/1000 acres
Jasper	32.9	26.8	25.6	31.9	44.4
Tyler	46.7	47.6	43.5	50.3	82.6
Polk	36.1	24.3	40.8	51.5	35.3
Hardin	54.1	57.1	38	9.5	13.2

Appendix D: Non-Deer Game Harvests in Big Thicket National Preserve from 1984-93.

These data are from BTNP Hunter Harvest data (BTNP 1993), which is determined from mailed surveys returned by permitted hunters.

Table D.1: Squirrel Harvests in BTNP from 1984-93, by year (BTNP 1993).

UNIT	92-93	91-92	90-91	89-90	88-89	87-88	86-87	85-86	84-85
Beaumont	1764	1596	2491	1162	1864	1132	2295	1067	0
Beech Creek	890	1123	1205	560	801	617	1057	918	1230
Big Sandy	1346	1850	1920	1503	1943	2094	3750	1479	4438
Neches Bottoms	982	1438	1895	1034	1287	665	2600	305	1140
Jack Gore Baygall	4377	4242	5598	2008	5021	4501	5453	2154	6455
Lance Rosier	8617	5246	6885	4391	7737	10754	8996	3628	13141
TOTAL	**17976**	**15495**	**19994**	**10658**	**18653**	**19763**	**24151**	**9551**	**26404**

Table D.2: Hog Harvests in BTNP from 1984-93, by year (BTNP 1993).

UNIT	92-93	91-92	90-91	89-90	88-89	87-88	86-87	85-86	84-85
Beaumont	62	0	1	5	5	4	26	11	0
Beech Creek	1	0	0	0	0	0	0	0	3
Big Sandy	1	0	0	0	0	0	1	2	1
Neches Bottoms	10	7	13	9	4	0	2	0	1
Jack Gore Baygall	34	6	14	0	1	0	0	10	4
Lance Rosier	146	61	78	65	80	129	139	64	134
TOTAL	**254**	**74**	**106**	**79**	**90**	**133**	**168**	**87**	**143**

Appendix D: Non-Deer Game Harvests in BTNP from 1984-93 (continued).

Table D.3: Rabbit Harvests in BTNP from 1984-93, by year (BTNP 1993).

UNIT	92-93	91-92	90-91	89-90	88-89	87-88	86-87	85-86	84-85
Beaumont	35	20	18	44	47	43	69	53	0
Beech Creek	49	16	58	58	17	33	38	32	89
Big Sandy	46	33	30	63	83	82	117	84	270
Neches Bottoms	16	43	17	16	17	12	55	4	18
Jack Gore Baygall	163	204	132	46	112	227	206	81	133
Lance Rosier	240	148	162	241	293	302	246	162	287
TOTAL	**549**	**464**	**417**	**468**	**569**	**699**	**731**	**416**	**797**

Table D.4: Waterfowl Harvests in BTNP from 1990-93, by year (BTNP 1993).

UNIT	92-93	91-92	90-91	89-90	88-89	87-88	86-87	85-86	84-85
Beaumont	9	0	0	NA	NA	NA	NA	NA	NA
Beech Creek	0	0	1	NA	NA	NA	NA	NA	NA
Big Sandy	27	0	0	NA	NA	NA	NA	NA	NA
Neches Bottoms	0	0	0	NA	NA	NA	NA	NA	NA
Jack Gore Baygall	0	22	14	NA	NA	NA	NA	NA	NA
Lance Rosier	33	0	1	NA	NA	NA	NA	NA	NA
TOTAL	**69**	**22**	**16**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

NA = not available

Appendix E: East Texas Timber Industry Effects on Water Quality in Big Thicket National Preserve

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A significant challenge to maintaining high water quality in BTNP corridor units lies in the need to limit pollution originating from forestry operations while not mandating inefficient management practices that might stifle the local economy. This report is a brief synthesis of recent pertinent articles on timbering effects on water systems and the regulations and protective measures associated with these effects. The literature on this subject is extensive (e.g. USEPA 1993), and the articles represented here are only a small portion of this large body of literature.

Silvicultural operations are generally recognized as nonpoint sources of pollution as pollutants emanate from diffuse origins including runoff, drainage, and seepage into surface or ground water (as distinguished from point sources, Section 208 of the 1972 amendments to the Federal Water Pollution Control Act of 1972). Control of nonpoint source pollution is pivotal to protecting water quality as it is estimated that 65% of the total pollution load to U.S. inland surface waters is attributable to NPS pollution (USEPA 1989). In silvicultural operations, much of this pollution is associated with the processes of harvesting and road construction (Hamilton 1994). Production of NPS pollution at any particular site is generally low. It is often the magnitude of operations that make silviculture a target of regulation (Gianessi *et al.* 1985, from Aust *et al.* 1994). Even so, assessments of states in the South show NPS impacts due to silviculture to rank far behind those due to other categories such as agricultural and urban sources (NCASI 1994)

Regulation of silvicultural operations and their impact on water quality in Texas is based upon four major federal statutes, the Federal Water Pollution Control Act (FWPCA) of 1948 and its amendments of 1972, 1977, and 1987. The 1948 Act is simply a non-regulatory action encouraging states toward voluntary goals of increased research and education. The Act's first major amendment of 1972 is a clear federal mandate for a reduction in water pollution from both point and nonpoint sources. Section 208 of the 1972 Amendments calls for implementation of state plans, under the eye of the EPA, to control nonpoint source (NPS) water pollution and specifically cites silviculture as an activity contributing to such pollution (Siegel 1991). The Federal Clean Water Act of 1987, which amends the FWPCA, includes Section 319, requiring each state to intensify

efforts to control NPS pollution by conducting individual water quality assessments and developing a state management program for NPS pollution.

The Texas Water Quality Act is the central state statute pertaining to NPS pollution issues. This Act appoints the Texas Water Commission (TWC) as the lead agency responsible for meeting the state's commitments to water quality legislation. The Act gives the TWC the power to grant authority over issues, permitting, and regulation in the control of NPS pollution in Texas. By delegation of the TWC, the Texas Soil and Water Conservation Board is responsible for control of NPS pollution from agricultural and silvicultural activities, and the Texas Forest Service (TFS) has specific management responsibilities over the state's silvicultural NPS control program (NCASI 1994).

All states are required by federal and state authority to promulgate voluntary Best Management Practices (BMP's) for silviculture and to determine "BMP effectiveness" including a measure of BMP compliance. According to the Texas Forestry Association (TFA), "BMP's can prevent, or at least greatly reduce, NPS pollution of water bodies from forestry activities (TFA 1990)." Some states, particularly in the West and East, have implemented regulatory or quasi-regulatory programs to enforce BMP's. Thirty-four states utilize nonregulatory measures, and most of these states couple these voluntary plans with BMP education. Seven south central states (AL, AR, LA, MS, OK, TN, and TX) subscribe to this non-regulatory approach, while the southeastern states (VA, NC, SC, GA, and particularly FL) tend to have more developed and stringent programs (NCASI 1994). Interestingly, in a comparative study of the Maryland regulatory program and Virginia's voluntary program, Hawks *et al.* (1993) found little evidence to prove either method more effective in obtaining overall BMP compliance. In fact, in terms of education, simplicity, and cost effectiveness, voluntary programs such as Virginia's were found to present a potential advantage.

Texas' nonregulatory approach is bolstered by the authority (currently unused) to invoke a limited regulatory program for blatant violators as well as the authority to make the state plan entirely regulatory if satisfactory results in water quality protection are not achieved (NCASI 1994). The TFA, not surprisingly, stresses the advantages of maintaining the voluntary program, pointing out "if everyone involved in forest management implements these practices, water quality can be protected without strict government regulation" (TFA 1990).

Regulations such as voluntary BMP's are designed in consideration of the greatest concerns of the USEPA in forestry-related NPS water pollution: sediment and debris, chemicals, and temperature change (Cornelius 1975, from Hamilton 1994). Special attention is given to the traditional pollutants, sediment and nutrients, as they are the primary cause of surface water impairment in the United States (Baker 1992). Sediment is the main source for NPS impairment of rivers and steams . Excesses of sediment can result in destruction of fish habitat, decreased recreational value, and sometimes dramatic losses of water storage capacity (Baker 1992). Not surprisingly, most BMP's are designed to control soil erosion and sediment loss (Golden *et al.* 1984, Nearly *et al.* 1989, from Aust *et al.* 1994).

An understanding of the effects various silvicultural methods have on sediment loss and water quality is vital to proper management and educated regulation of timbering. Blackburn *et al.* (1986) found that sediment loss and storm flow in East Texas forestland vary according to method of site preparation. Sediment concentration and loss from an undisturbed watershed are relatively low, marked only by occasional increases due to dramatic climatic conditions. As might be expected, both common harvest preparations of (1) clearcutting, shearing, windrowing, and burning, and (2) clearcutting, roller chopping, and burning generally increase the rate of sedimentation by removing stabilizing vegetation, but mean annual sediment loss was significantly greater from sheared sites than from those which were chopped or undisturbed. Even between commonly accepted methods there is significant variation in sediment loss.

In a study of a palustrine water tupelo-bald cypress swamp in southwestern Alabama, Aust *et al.* (1991) found variation according to treatment in the abilities of sites to remove sediment (NPS pollution) from flood waters. Aust *et al.* found that sites using helicopter removal of logs trap more sediment than similar sites on which the effects of a skidder were simulated. This difference was attributed to the erosion of skidder ruts in rainfall and the disturbance of low-lying vegetation by the skidder. Both of these sites removed more sediment from water than a study site logged by helicopter and treated with a herbicide. The lack of regrowth of herbaceous and woody vegetation seems to diminish capacity for trapping sediments. Both of the logging-only sites, perhaps also due to vegetation regrowth, removed more sediment from flood waters than even the untouched control sites. Interestingly, at least in the short term, these treatments seem to result in a potential for increased water quality. However, the issue is more complex: Aust and Lea (1992), studying the same sites, found skidder use to negatively affect soil hydrology, decreasing oxygen content, raising the pH, and thus altering the physical and chemical

characteristics of the area. Not surprisingly, making the "right" and feasible choice among silvicultural methods to reduce NPS pollution can involve compromise among other seen and unseen factors at any particular site. Even so, particular silvicultural methods can have a significant and predictable effect on the volume of sediment and other pollutants that reach local water systems .

Other than harvesting and site preparation, the remaining major silvicultural source of NPS pollution is road construction and its associated activities (Hamilton 1994). Erosion associated with stream crossings of both temporary and permanent logging roads represented the most significant problem encountered in a study of BMP compliance and effectiveness in East Texas (Lord *et al.* 1992). Compaction of surface soil as occurs in road construction may cause an increase in surface runoff. Many of the BMP guidelines for road construction suggest methods including ditches, culverts, and sloping grades for properly channeling this runoff and decreasing erosion (TFA 1990).

Chemical contamination is yet another concern addressed in the combined federal and state pursuit to control NPS pollution of local waterways by silvicultural operations. The need to increase timber yields on a diminishing land base at a reduced cost has brought about an increasing use of fertilizers and pesticides in the last decade. Excess nutrients, often originating from fertilizer runoff, are the foremost cause of NPS impairment of lakes and estuaries. This is not only a concern for silviculture, as agriculture is accountable for a vast majority of this runoff pollution and is the primary focus for control in this area of NPS pollution (Baker 1992).

Herbicides are among the most common silvicultural chemicals, with a large number of compounds registered for use by the EPA. Within this list, less than a dozen herbicides account for most silvicultural usage, both in frequency of use and in total volume. These herbicides are 2,4-DP, dicamba, fosamine, imazapyr, picloram, sulfometuron methyl, tebuthiuron, and particularly 2,4-D, glyphosate, hexazinone, and triclopyr. Buffer zones tend to control peak streamflow and stormflow concentrations and keep peak residue concentrations low (Neary *et al.* 1993). Particularly dangerous situations tend to arise only where such chemicals are mishandled in high concentrations or applied directly to waterways (TFA 1990). Texas' state BMP's offer procedural suggestions designed to avoid such situations. Used correctly, the infrequent application, low concentration, and lack of persistence of forestry chemicals has not yet been found to pose a significant risk to local water quality, particularly not in comparison to the effects of erosion and sedimentation (Neary *et al.* 1993).

Silvicultural operations have been shown to increase water temperatures by removing the shading forest canopy. Such a rise in temperature could lead to significant changes in the aquatic and neighboring environments. Rutherford *et al.* (1992) found short-term change in local fish assemblages associated with clearcutting in Southeastern Oklahoma. No evidence of extinction was seen over the two decade study period, but, as this study points out, "short-term effects summed over long periods of time may have profound effects on faunal structure."

Although reconsideration of forestry methods and land use may be necessary to decrease NPS pollution, such actions are not strictly regulated by law. Instead, responsible options are presented to owners, foresters, and industry in the form of voluntary state BMP's. BMP's are a portion of the Nonpoint Source Management Program as developed by the Texas State Soil And Water Conservation Board. The pertinent silvicultural sections of this management program were modeled after those of Arkansas and developed with contributions from both the Texas Forestry Association and the Texas Forest Service. First established and made available in 1990, this compiled information is available as a manual through the Texas Forestry Association (TFA 1990). The bulk of BMP guidelines outline procedures for planning, constructing, and maintaining an economically viable silvicultural operation with a minimal impact on local waters. Recommendations are often not overly specific in regards to method, but instead are concerned with physically isolating, or at least buffering waterways from the possibly harmful effects of road construction, harvesting, site preparation, and chemical use. As has already been observed in site preparation and harvesting, a simple choice of method in any of these areas can make a potentially significant difference in decreasing nonpoint source pollution.

The Federal Clean Water Act of 1987 required the Texas Forest Service to develop and implement a monitoring program to evaluate the effectiveness of Texas' voluntary BMP program. This effectiveness was to be based on the degree of compliance to BMP standards found within the state as well as the actual ability of BMP's to reduce NPS pollution. The monitoring program established by TFS has completed only an initial survey in 1991 and 1992 so far. Using a simple checklist of 73 "yes or no" questions, site compliance to BMP standards was recorded by TFS foresters, and a subjective "Overall Compliance Rating" of Excellent, Good, Fair, Poor, or No Effort was given. A TFS report by Lord *et al.* (1992) summarizes this monitoring of 162 sample sites intended to be representative of the variations by region and ownership of silvicultural operations within the state. The authors found BMP compliance to be relatively high with 88% of sites receiving a rating of Fair or better. The report stated BMP's were effective in reducing

water pollution (primarily from sedimentation), with failures resulting from improper implementation of suggested practices. The southern regional report of the NCASI (1994) maintains that established BMP's have demonstrated their effectiveness in controlling management effects on water quality. Aust *et al.* (1994), in studying Virginia's program, and Brown *et al.* (1993), looking at results in Georgia, Texas, Idaho, California, Washington, and two detailed studies, also conclude that BMP's are generally effective when properly applied.

The Streamside Management Zone (SMZ) is one BMP that is commonly cited as a representative example of the flexibility, simplicity, and effectiveness of BMP's in nonpoint source pollution control (Lowrance *et al.* 1984, Anderson and Masters 1992, Belt *et al.* 1992). The Texas Forestry Association defines an SMZ as the "area on each side of the banks and above the head of intermittent streams, perennial streams, and other drains or bodies of water where extra precaution in carrying out forest practices is needed to protect bank edges and water quality" (TFA 1990). Such an area is maintained around streams and pools where disturbances may result in substantial erosion in order to trap sediments before they can reach the body of water in question.

The guidelines for maintenance of SMZ's require a minimum width of 50 feet on either side of a stream. The suggested width of this buffer zone can increase with the slope of land adjacent to the waterway and depending upon the purpose of the buffer zone (TFA 1990, Anderson and Masters 1992). For example, streams feeding municipal water sources require a minimum SMZ width of 100 feet under conditions of minimal slope. A zone of at least 200 feet is required for slopes of 45 degrees or more. Limited harvesting is allowed in SMZ's as long as 50% of original crown cover or 50 square feet of basal area per acre is retained and the forest floor remains relatively undisturbed to facilitate the natural filtering process by organic litter. Otherwise, activity within the area of the SMZ is extremely limited (TFA 1990).

Not only is water quality protected by establishing such streamside buffers, but study suggests a variety of other advantages as well. Diverse environmental processes and resident species of riparian corridors may prove essential to understanding and maintaining regional biodiversity (Naiman, Decamps, and Pollock 1993, Decamps 1993). SMZ's provide shade to maintain stream temperatures for fish habitats, an inhabitable and vital zone for wildlife, and local recreational possibilities (Anderson and Masters 1992). Also, study of riparian forest zones by Lowrance *et al.* (1984) has shown that these SMZ's can potentially function, not only as deterrents to erosion, but also as short- and long-term nutrient filters and sinks if periodic tree harvesting is utilized to ensure a net uptake and

removal of nutrients by growing vegetation. Soil and vegetation in the riparian forest ecosystem can prevent outputs from agricultural uplands from reaching the stream channel. Such nutrient filtering could prove invaluable in protecting stream channels from agroecosystem discharge (Lowrance *et al.* 1984). There is no reason not to assume similar beneficial results in the case of "tree farming" when considering that the use of potentially dangerous chemicals in silvicultural activities is far less frequent than in most modern agricultural methods. In support of this assumption, the results of Neary *et al.* (1993) show low peak residue concentrations of pesticides in southern forests except in cases where buffer strips were not properly established. An elegantly simple protective measure, the SMZ, if properly and widely implemented, seems to provide a broad defense against possible silvicultural impacts to stream channels and water quality.

Although the forestry operations of East Texas possess a significant potential to negatively impact the region's water quality, state BMP's seem to be proving effective as a step in balancing the requirements of industry with the necessity of water quality protection in this forestry-dependent region. Obviously, room for significant improvement exists in both efficiency and compliance. Perhaps revisions distilled from the experience of Texas and other states with the continuing cooperation of the silvicultural industry may be able to provide a source of optimism that water quality impacts may be minimized with maximum cost effectiveness for local industry (Brown *et al.* 1993, Lord *et al.* 1992). If not, it is well within the power and responsibility of the state to strictly regulate silvicultural activity to protect the future of local water quality.

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Appendix F: Location of Supporting Computer Files

All computer files comprising or supporting this document have been retained by Dr. P. A. Harcombe, Dept. of Ecology and Evolutionary Biology, Rice University . The files are located on the computer "Global Changer" in the directory \Lab Projects\WCMP. The list below indicates the name and subdirectory for the files comprising this document and the supporting databases. Not all supporting files are listed below.

Document Parts:	
Main Document	\WCMP BTNP Biological Resources
Appendix A.1	\WCMP Appendix A.1 Bird List
Appendix A.2	\WCMP Appendix A.2 Mammals List
Appendix A.3	\WCMP Appendix A.3 R & A List
Appendix A.4	\WCMP Appendix A.4 Fish List
Appendix A.5	\WCMP Appendix A.5 Invert List
Appendix B	\WCMP Appendix B Endangerd sp.
Appendix C	\WCMP Appenidix C Deer Harvests
Appendix D	\WCMP Appendix D Non-deer game
Appendix E	\WCMP Appendix E Timber Effects
Appendix F	\WCMP Appendix F File Locations
Supporting Filemaker Pro Databases:	
BLHF/BITH Species Database	\Databases\WCMP species list FMP 2.1
Document References and Notes	\Databases\WCMP Reference Notes